THE WHEAT PLANT

A MONOGRAPH

BY

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WITH 228 ILLUSTRATIONS

LONDON
DUCKWORTH AND CO.
3 HENRIETTA STREET, COVENT GARDEN, W.C.

First published in 1921.

TO MY

FATHER AND MOTHER

PREFACE

MORE than twenty years ago, when first engaged in the teaching of botany to agricultural students, I became aware of the botanist's neglect of cultivated plants, and in the preparation of my text-book of *Agricultural Botany* found it necessary to make a first-hand study of all the common crops before any living interest could be created in the work I had undertaken.

I then determined upon a more intensive study of the chief farm plants with a view of writing a series of botanical monographs upon them as opportunity permitted.

Administrative duties and teaching have prevented me from carrying out the project as designed. Nevertheless, I have kept alive the intention, and the present monograph is an embodiment of researches made upon the wheat plant.

I hope that it may serve in a modest way as a model of the research that is needed upon all farm plants, and act as a stimulus to further effort.

The plants with which the farmer has to deal provide limitless fields of exploration for the plant physiologist, anatomist, student of variation and heredity, and indeed all ranks of botanists. Their study will satisfy the most ardent aspirations of the academic mind in its pursuit of so-called pure science, and the discoveries to be made cannot fail to be of service in enabling the cultivator to obtain higher economic returns from the soil on which all animal life ultimately depends.

In Part I. of the monograph are given the results of my investigations of the morphology, anatomy, growth, and development of the wheat plant. Except where otherwise indicated, the various measurements and illustrations refer to the ordinary dense-eared type of Bread wheat (*T. vulgare*) commonly grown in Great Britain.

In Part II. are described and discussed the taxonomy, characters, and relationships of the wild species of wheat and the races and varieties of

cultivated forms. This section of the work is based upon a prolonged study of the living plants, forming what may be termed the Reading Collection. The latter, which is grown annually at the University College Farm, is probably the most representative collection in existence, and includes all the races of wheats numbering nearly two thousand forms derived from almost all wheat-growing regions of the world.

For assistance in obtaining these I am especially indebted to the Ministry of Agriculture and Fisheries and the Foreign Office; to Dr. Regel and M. C. Flaksberger of Petrograd and Dr. Vavilov of Moscow for Russian and Central Asiatic wheats; Professor Kozai, Tokio, for Japanese wheats; H. M. Leake, Esq., Economic Botanist to the Government of the United Provinces, and D. Milne, Esq., Economic Botanist, Punjab, for Indian wheats; and numerous workers in other countries.

I desire also to express my thanks to the Council of the College for the provision of facilities for research; to Miss Mason and Mr. F. O. Mosley for assistance with experimental work; and to Professor Pennington for his enthusiastic interest in the wheat collection and the cultivation and testing of selected forms.

To Miss Erith, Lecturer in Agricultural Botany, I owe a debt of gratitude for faithful assistance with records and experimental investigations during the last three years, and for the onerous task of proof-reading.

All the illustrations are original, those of the ears of the various races of wheat being natural size.

JOHN PERCIVAL.

University College, Reading.

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PART I

CHAPTER I

INTRODUCTORY

AMONG the world's crops wheat is pre-eminent both in regard to its antiquity and its importance as a food of mankind.

In prehistoric times it was cultivated throughout Europe, and was one of the most valuable cereals of ancient Persia, Greece, and Egypt.

Although rice is the principal food of a large proportion of the human race, a greater amount of wheat is grown, and this, in the form of bread, constitutes the chief food of the most highly civilised races.

In Russia and parts of Northern and Central Europe rye is the staple food, as it was until comparatively recent times in Great Britain and Western Europe generally; but with improvements in the standard of living, wheat is substituted for rye in the diet of the people, and its cultivation and consumption are being continually extended.

On account of the peculiar physical and chemical qualities of the gluten of its grain, wheat makes more palatable and better bread than any other cereal.

Its cultivation is simple, and its adaptability to varying soils and climatic conditions superior to that of any other plant.

Originating from two or three wild species, through hybridisation, mutation, and the effects of selection and cultivation, the races of wheat have become as complex in constitution as the human race, and among the almost endless number of varieties and forms which exist, wheats are to be found suitable to the needs of agriculturists in all parts of the world.

Wheat is grown in every country in Europe and Asia, with the exception of Siam, and large areas are devoted to it in Australia and New Zealand.

In Africa it is an important crop in Abyssinia, the Union of South Africa, and along the Mediterranean coast from Egypt to Morocco. Within the Tropics it is also grown in British East Africa and Nigeria.

In the Western Hemisphere the vast wheat-fields of Canada and the United States are well known, and it is grown in Mexico and most of the Central American Republics. It is also cultivated in nearly all the countries of South America.

The only parts of the world from which it is absent are the hot, low-lying regions of the Tropics.

The greatest wheat-growing countries are Russia, the United States, India, France, Canada, Italy, and Argentina. With the exception of France and Italy, all these produce more than they require, and export the surplus to regions which do not grow enough for their needs. Larger or smaller imports enter every country in Western Europe, by far the largest amount being taken by the British Isles.

The crop is being harvested in one country or another all the year round as indicated below:

January.—Australia, New Zealand, Argentina, Chili.

February.—India.

March.—India, Upper Egypt.

April.—India, Persia, Asia Minor, Lower Egypt, Mexico, Cuba.

May.—Japan, China, Central Asia, Morocco, Algeria, Tunis, Texas.

June.—South France, Spain, Italy, Greece, Turkey, Japan, United States south of 40°.

July.—France, Germany, Austria, Hungary, Roumania, Bulgaria, Southern Russia, Canada, Northern United States.

August.—England, Northern France, Belgium, Holland, Central Russia, Canada, United States.

September.—Scotland, Sweden, Norway, Canada.

October.—Northern Russia, Finland.

November.—South Africa, Argentina, Peru.

December.—Burma, Australia, Argentina.

The great wheat-producing areas of the world are found in the temperate regions between the parallels of latitude 30°-60° N. and 27°-40° S.

Wheat can, however, be grown from beyond the Arctic circle to the Equator.

In Europe it has yielded ripe grain as far north as 69° 28′ N. at Skibotten on the Lyngenfjord in Western Norway, and in European Russia it is cultivated around Archangel in latitude 64° 33′ N. The northern limit of growth in Great Britain is the Orkney Isles about 59° N., though its profitable culture does not extend beyond 51° or 52° N.

In Asiatic Russia Flaksberger reports the growth of spring wheat at Verkhoyansk in Siberia, within the Arctic circle.

In the Western Hemisphere spring wheats mature in Alaska up to 60° N. In the Peace River valley in Canada a flour-mill is maintained at Fort Vermilion, and ripe grain has been produced up to 65° N. on the Mackenzie River.

It is grown at the Equator on the high lands of Ecuador and Colombia, and its cultivation is carried on in British East Africa and Nigeria.

Other countries within the Tropics in which the cereal is grown are

India, Arabia, the Philippine Islands, Peru, Brazil, Venezuela, Salvador, and other Central American Republics.

Wheat has also a wide altitudinal range. In this country it is grown from sea-level up to about 600 feet.

Farther south, in the Swiss Alps and the Pyrenees, spring wheats can be grown at an elevation of 4000 feet, and in the Tropics their cultivation is carried on at an elevation of 8000-10,000 feet in Mexico, Colombia, Ecuador, and Abyssinia.

Humboldt records its growth at an altitude of 14,000-15,000 feet in Tibet.

The greatest amount of the best wheats are produced in countries where the winters are cold and the summers comparatively hot. So long as the winter temperature does not fall below −20° C. and the air and soil are dry, the exposed plants suffer little, but at lower temperatures the crop is damaged, and in some cases killed outright, unless protected by a covering of snow.

In regions of severe winters with cold winds and little snow only spring wheats are grown, the autumn-sown winter wheats being reserved for districts with a higher mean winter temperature, or where a sheltering layer of snow is certain.

For the most satisfactory growth and development of the grain a cool, moist, growing season followed by a bright, dry, and warm ripening period of 6-8 weeks, with a mean temperature of 18-19° C. (about 66° F.), is necessary.

In those parts of this country where the mean temperature of June, July, and August is below 13-14° C. (56° or 57° F.) wheat is a hazardous crop.

In regard to the water-supply essential for the wheat crop, an annual rainfall of 20-30 inches is sufficient, so long as the greater proportion of it falls during the growing season. Some of the Macaroni and Club wheats are capable of yielding remunerative returns in regions where the rainfall is not more than 12-15 inches per annum, and there are records of crops of Macaroni wheats grown in arid districts without any rainfall between sowing and harvest, the necessary water being derived from the rain stored in the soil from the previous season.

Wheat is grown chiefly for its grain, which is ground and utilised in the form of flour for the manufacture of bread and biscuits.

Some varieties are employed in considerable amounts in the preparation of macaroni and similar pastes, and most of the "cracked," "shredded," and "malted" "cereal foods" consist of specially treated wheat. Occasionally the grains are cooked whole, and consumed with milk, or used in soups in place of pearl barley.

Although the grain is useful food for farm animals, its production is

too costly in comparison with the cereals maize, oats, and barley to allow of its being used for this purpose on a large scale.

The so-called " milling offals," however, consisting of the bran or husk and other portions of the grain, obtained as by-products in the manufacture of flour for bread-making, are among the most valuable foods for all kinds of stock.

In the great wheat-growing regions the straw of the crop is of little value, and is burnt or ploughed in, its humus and mineral constituents serving to improve the physical and chemical condition of the soil. On more intensively cultivated lands the straw is of greater importance to the farmer, being employed as thatch for stacks, food for stock, or as litter for the bedding of farm animals, in which latter case it is ultimately returned to the soil as manure.

In addition to its agricultural value, wheat straw is utilised in the manufacture of mattresses, straw hats, and paper.

CHAPTER II

THE GRAIN : STRUCTURE, COLOUR, AND OTHER CHARACTERS

A GRAIN of wheat, often spoken of as a "seed" by farmers, is a nut-like fruit termed by botanists a caryopsis, a name first used by Richard.

It contains a single seed or kernel enclosed within a thin shell; the seed, however, instead of being free as in many nuts, is adherent to the inner wall of the pericarp or shell, and the two cannot be separated readily.

As indicated later, the grains of different kinds of wheat vary considerably in size, form, and colour: they nevertheless all resemble each other in fundamental structure, being fruits with thin-walled pericarps, each containing a single seed, the latter consisting of four parts, viz.: (1) the *seed-coat* or *testa*, sometimes termed the *spermoderm*; (2) the *embryo* or young wheat plant; (3) the *nucellar layer*; and (4) the *endosperm* or floury part—a thin-walled parenchymatous tissue stored with food for the nutrition of the embryo when germination commences.

From careful dissection of several grains and weighing of the separate portions the embryo was found to weigh from 2·8 to 3·5 per cent of the grain; the pericarp, seed-coat, nucellar layer, and aleuron layer from 7·8 to 8·6 per cent; the rest, or some 87 to 89 per cent, being the endosperm-parenchyma, containing starch and gluten.

Ordinary white flour consists chiefly of the finely ground endosperm, the so-called "milling offals" consisting of the broken pieces of pericarp, seed-coat, aleuron layer, and the embryo, the latter being usually separated from the other portion of the grain.

The Pericarp.—The dorsal surface of the pericarp of a grain of wheat is smooth and rounded, the opposite or ventral side having a characteristic inward fold or furrow called the "crease" by millers.

At the base is a small wrinkled patch—the part of the pericarp which covers the embryo plant within. The apex is clothed with a number of short stiff hairs, which curve inwards towards a common point, and form the "brush" of the grain. The surface covered by the "brush" slopes slightly to the furrow side, and is somewhat triangular in outline; among its hairs the remains of the styles are found.

In most parts the pericarp of the ripe grain is 45-50 μ thick and composed of four or five layers of cells, namely, an outer and inner epidermis with two or three layers of parenchyma between.

The outer epidermis is formed chiefly of elongated cells from 125 to 210 μ long and 25-30 μ broad; the cell walls, which are about 5-7 μ thick, are perforated with pores, and in surface view appear beaded (Fig. 1). The cells are arranged lengthwise from base to apex of the grain; near the apex they become shorter, some of them being almost square.

Belonging to the epidermis are the hairs of the "brush"; these are single, fine-pointed cells ·5 mm. to 1 mm. long, each with a more or less

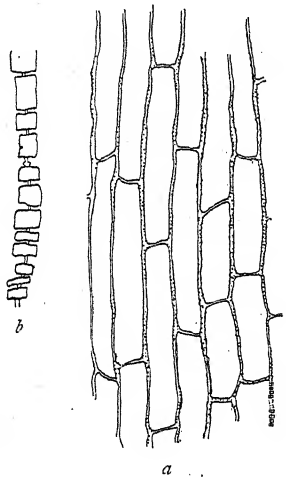


FIG. 1.—*a*, Cells of the outer epidermis of caryopsis ($\times$ 260); *b*, wall of cell showing thickening ($\times$ 385).

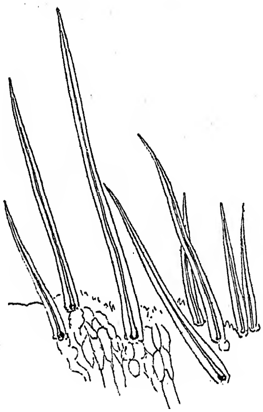


FIG. 2.—Hairs of the "brush" at the apex of the caryopsis ($\times$ 105).

bulbous base; their cell cavities are of smaller diameter than the cell walls, which have a thickness of about 6 μ (Fig. 2).

Beneath the epidermis are one or two layers of thick-walled parenchyma and an irregular layer of similar tissue, the cells of which have thin walls, and are crushed and often disorganised.

Succeeding these is a well-defined layer consisting of elongated cells, the largest diameters of which are arranged at right angles to those of the epidermal cells, and therefore across the grain. The cells of this "cross layer" in the young grain contain chlorophyll, but in the ripe grain are empty like the rest of the pericarp cells. Except at the apex and base of the grain, where they are shorter, they are usually from 100 to 150 μ long and 15-20 μ broad, with walls 5-7 μ thick, in which are irregular slits or pores.

In adapting themselves to the shrinking grain when ripening takes

place, these cells become more or less crumpled or bent, often leaving small intercellular spaces where the ends meet (*a*, Figs. 3, 4, and 5).

Immediately within the "cross layer" is the inner epidermis of the pericarp. It consists of thinner-walled vermiform or hypha-like cells, termed "tube-cells" by Vogl, from 120 to 250 μ long and 12 to 15 μ wide; they lie parallel to the outer epidermal cells running from base to apex, and in a ripe grain are either separated from each other altogether by wide spaces or are joined only at irregular intervals.

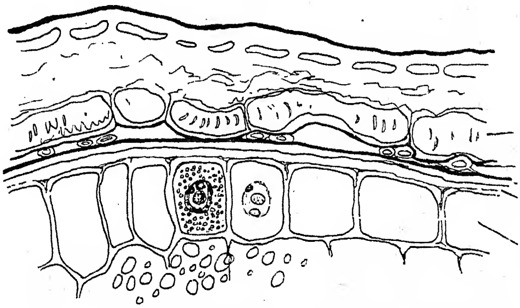


FIG. 3.—Transverse section of the pericarp and aleuron layer of a ripe grain (×210). *x*, Epidermis; *a*, "cross layer"; *b*, "tube-cells" (inner epidermis); *d*, testa; *e*, crushed nucellar layer; *g*, aleuron layer.

In transverse or longitudinal sections of the ripe grain these "tube-cells" are difficult to observe, since they are isolated and do not form a continuous layer, and the individual cells are crushed into close contact with the testa beneath; their outlines, however, are easily seen when surface views of strips of the soaked pericarp are examined after the outer epidermis has been removed (*b*, Figs. 3 and 5).

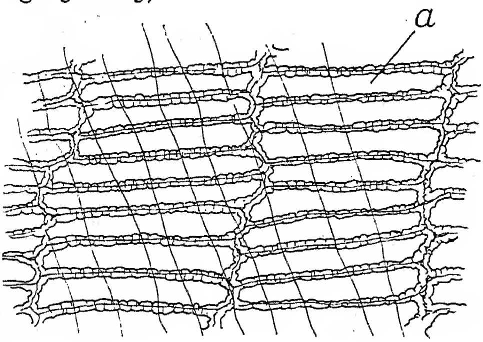


FIG. 4.—Surface view of the cells (*a*) of the "cross layer" of the pericarp, with thin-walled cells of the testa crossing them (×210).

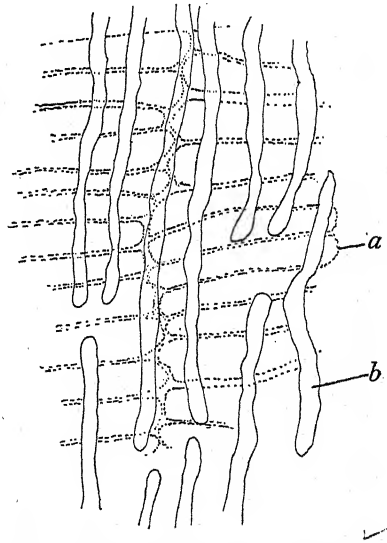


FIG. 5.—*a*, Cells of the "cross layer" of the pericarp (×210); *b*, tube-cells of the pericarp.

The pericarp in the central region of the furrow is thicker than on the opposite side, and in it are usually developed one or two vacant spaces, where the tissue has been torn asunder during the ripening of the grain.

From the point at the base of the grain where the latter was attached to the rachilla, a delicate vascular bundle traverses the pericarp upwards along the furrow to near the base of the style.

The Seed.—Within the pericarp is the seed, consisting of *testa*, *nucellar layer*, *endosperm*, and *embryo*.

(*a*) *Testa.*—In a transverse section of a ripe grain of red wheat, the testa or seed-coat, to which the colour of the grain is chiefly due, is seen as a reddish-brown line immediately next to the " cross layer " (*d*, Figs. 3, 109), the " tube-cells " being usually invisible. It is derived from the inner of the two ovular integuments, and consists of two layers of elongated cells, the lumina of which have been obliterated by the crushing together of the upper and lower walls ; the cell walls of the outer layer are almost colourless, those of the inner one being tinted red or brown. On account of their extreme tenuity the separate layers cannot be distinguished in transverse sections of ripe grains, but after treatment of the pericarp with a solution of caustic potash, surface views of them may be obtained, when they appear composed of thin-walled parenchymatous cells, 100-150 μ long and 15-20 μ broad ; the long axes of the cells of the outer layer cut the " cross layer " almost at right angles, the inner cells being arranged across the latter at an acute angle (Figs. 4 and 6).

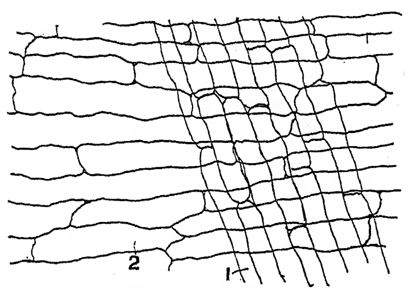


FIG. 6.—Surface view of the two cell-layers of the testa ($\times 210$). 1, The outer; 2, the inner layer.

The seed-coat covers the embryo and endosperm, and is folded in the centre of the furrow, where it joins the funicle of the seed.

(*b*) *The Nucellar Layer.*—Next to the reddish-brown seed-coat is a bright colourless line—the so-called " hyaline layer "—possessing no apparent cell structure (*e*, Figs. 3, 109). It is the epidermis of the nucellus, the inner and outer walls of which have been crushed together, so that the lumen of the cells is not visible in transverse sections. The cells are more or less rectangular and oblong ; their outline may be seen on examining portions of the soaked pericarp.

(*c*) *The Endosperm.*—With the exception of the small space occupied by the embryo the endosperm tissue fills the interior of the grain. It may be divided into two parts, viz. : (1) the so-called " *aleuron layer* " and (2) the *starch- and gluten-parenchyma.*

The *aleuron layer* surrounds the rest of the endosperm, closely following the contour of the seed-coat. It is almost entirely one cell thick, measuring about 65-70 μ across (*g*, Fig. 3) ; only in the furrow, and occasionally at other parts, are two or more cells superposed. The individual cells are

rectangular in transverse and longitudinal sections, and polygonal, with rounded corners in surface view, varying in diameter from 25 to 75 μ, and having walls about 6 μ thick (Fig. 7). In front of the scutellum the layer consists of smaller cells, while over the plumule and coleorhiza it becomes so very thin and shrivelled that it is difficult to recognise it as a separate layer. Formerly the cells were termed "gluten cells," but Schenk in 1872 showed that they contain no gluten. In each is a round or oval nucleus about 12 μ in diameter and possessing three or four nucleoli. The rest of the cell cavity is filled with minute spherical bodies, usually described as aleuron grains, imbedded in a small amount of waxy or oily cytoplasm. Each grain measures about 3 or 4 μ in dia-

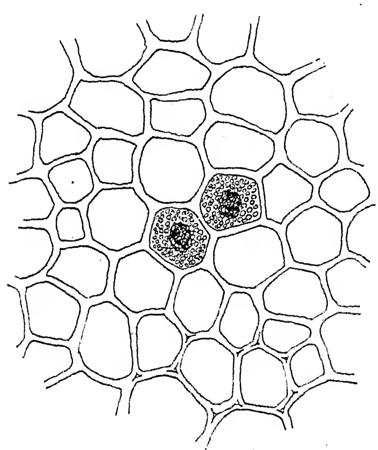


FIG. 7.—Surface view of the aleuron layer ($\times$210).

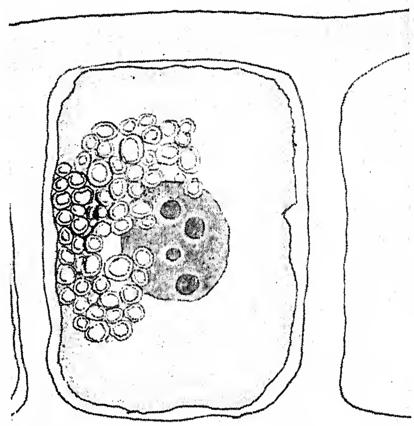


FIG. 8.—Cell of the aleuron layer after treatment with dilute alcohol, showing nucleus and insoluble membranes of the "aleuron grains" ($\times$770).

meter, and consists of a highly refractive core surrounded by a thin membrane. When treated with water, salt solution, or weak acids or alkalies, the core dissolves, leaving the insoluble membrane as a hollow ball (Fig. 8). O'Brien considers that the homogeneous core consists of a soluble protein which, according to Groom, contains a small amount of magnesium and calcium phosphates, but neither globoid nor crystalloid as found in typical aleuron grains are present in these granules.

The *starch- and gluten-parenchyma*, forming by far the greater portion of the wheat grain, consists of thin-walled polyhedral cells, with their long axes arranged usually at right angles to the surrounding pericarp. Adjoining the aleuron layer, they are comparatively small, becoming two or three times as large in the central parts of the endosperm. In contact with the back of the scutellum of the embryo the cells of the endosperm

parenchyma are crushed together, forming a narrow band 35-40 μ broad, devoid of starch (*r*, Figs. 10 and 11). The majority of the cells, however, are filled with starch grains imbedded in a protoplasmic matrix, from which gluten is derived on treatment with water; more or less disintegrated nuclei may be recognised, but no aleuron grains are present. The starch grains in the cells immediately within the aleuron layer are small — 8 to 10 μ in diameter — and more uniform in size than those found in the larger inner cells of the endosperm. In the latter two forms are seen, namely, large lenticular grains of circular or elliptical outline measuring from 28 to 40 μ across, and much smaller grains almost spherical, rarely more than 6 or 8 μ in diameter. In each of the larger grains is a small central hilum surrounded by faint rings.

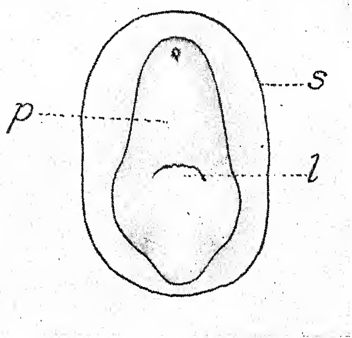


FIG. 9.—Front view of the embryo. *s*, Scutellum; *p*, plumule; *l*, epiblast.

(*d*) *The Embryo.* — The embryo of the wheat plant lies on the dorsal side at the base of the grain, one side of it in close contact with the endosperm, the other being covered only by the seed-coat and pericarp.

It is a highly differentiated body, possessing a short hypocotyl, at the apex of which is the *plumule* or primary bud, composed of rudimentary leaves surrounded by the *coleoptile* or plumule-sheath, and at its base, the root-system, completely enclosed by the *coleorhiza* or root-sheath (Figs. 9 and 10).

Attached to one side of the axis, and forming the greater portion of the embryo as it exists in the grain, is a fleshy shield-like structure named by Gärtner the *scutellum*; on the other side, opposite to the scutellum, is a small, tongue-like organ termed the *epiblast* by Richard (*e*, Fig. 10).

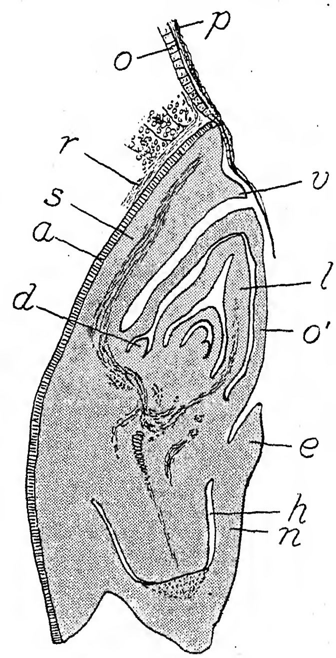


FIG. 10.—Longitudinal section of the embryo (×25). *p*, Pericarp of the grain; *o*, aleuron layer; *r*, crushed empty cells of the endosperm; *s*, scutellum; *a*, epithelium of scutellum; *v*, "ventral" scale of scutellum; *o'*, coleoptile; *l*, 1st grain foliage leaf; *e*, epiblast; *h*, primary root; *n*, coleorhiza; *d*, bud in axil of coleoptile.

(i.) The *scutellum* resembles a broad elliptical shield, measuring 3 mm. by 2·5 mm. and about ·3 mm. in thickness, with a thinner rim. It is slightly curved, the convex surface fitting closely to the endosperm. The upper free portion extends about 1·3 mm. beyond the point of attachment to the axis, and partly surrounds the coleoptile, the latter being sunk in a slight depression in the scutellum. The portion which projects over the apex of the coleoptile is sometimes termed the *cotyledonary sheath* or *ventral scale* (*v*, Figs. 10, 107).

The epidermis of the back of the scutellum in contact with the endosperm consists of elongated cylindrical cells 35-40 μ long and 8-10 μ broad, the long axes of which are arranged at right angles to the curved

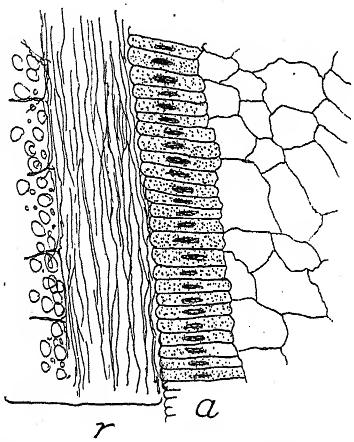


FIG. 11.—Transverse section of a portion of the back of the scutellum and adjacent endosperm (×210). *a*, Epithelium of the scutellum; *r*, crushed empty cells of the endosperm.

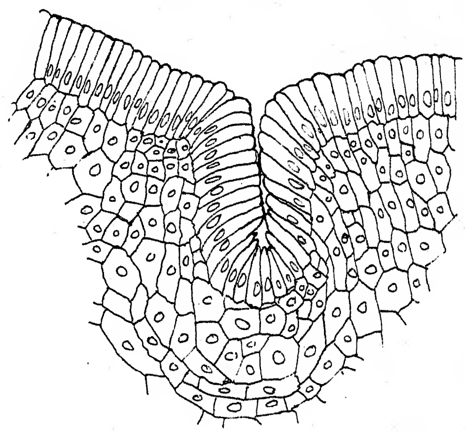


FIG. 12.—Gland-like cavity from the scutellum of *T. dicoccum* (×200).

surfaces of the scutellum (*a*, Figs. 10 and 11). It is termed the *columnar epithelium* or *epithelial layer*; and in the embryos of *T. dicoccum*, *T. durum*, and some other wheats, portions of it are deeply inverted into the form of simple tubular glands, especially near the upper and lower edges of the scutellum (Fig. 12). Its cells secrete diastase, the enzyme which renders soluble the reserve starch stored in the endosperm tissue, and it functions also as a haustorium through which all the dissolved plastic materials of the endosperm are absorbed and transferred to the embryo when germination occurs.

(ii.) The *epiblast* or *lobule* is a short, thin scale (*e*, Fig. 10) about 170 μ long, 550 μ broad at the base, and about 82 μ thick; it is attached to the axis slightly above the point of insertion of the scutellum, and consists of parenchyma only, with no vascular system.

(iii.) The *coleoptile* or *plumule-sheath* is a protective leaf, which completely encloses the plumule, except near the apex, where, on the side opposite to the scutellum, there is a minute opening (Figs. 9 and 10), through which the first green leaves of the plumule ultimately make their way. It springs from the same side of the axis as the scutellum and immediately above the point of insertion of the latter organ. In the resting embryo it is short—about 1 to 1·25 mm. long—but as it pushes its way upwards through the soil when the grain is sown, it lengthens, and may grow to a length of 1 or 2 inches.

(iv.) The *plumule* within the coleoptile consists of two or three rudimentary leaves surrounding the growing point. These have a divergence of $\frac{1}{2}$, the first being on the side of the axis opposite the scutellum. In addition to the primary bud there is in the wheat embryo a secondary lateral bud in the axil of the coleoptile on the side next to the scutellum (*d*, Fig. 10).

(v.) *The Root-system.*—The embryo in a grain of Bread wheat possesses a well-differentiated root-system, consisting of five rootlets, namely, a primary radicle directed slightly forwards and two pairs of secondary lateral rootlets, which arise from the short axis of the embryo in a plane almost parallel to the face of the scutellum.

The roots of the lower older pair, which arise just above the point of insertion of the epiblast, are not so large as the primary radicle; those forming the upper younger pair are very much smaller. Another single rootlet often grows out in front above the epiblast between the lateral pairs, but it is rarely differentiated in the resting embryo of wheat, although it frequently appears after germination is well advanced (*b*, Figs. 18, 22).

Later still, a pair of opposite rootlets arise above the other pairs and parallel to them, the seedling plant then possessing eight rootlets.

Each of the rootlets terminates in a growing point covered by a root-cap, and the primary and two lowest pairs just mentioned are enclosed within the *coleorhiza* or root-sheath, a parenchymatous tissue connected with the hypocotyl and the lower half of the scutellum.

(vi.) *The Vascular System.*—The vascular system is clearly defined in the resting embryo in the form of procambial strands, consisting of elongated thin-walled conducting cells of polygonal section, each from 50 to 80 μ long and 6 to 8 μ in diameter.

A broad strand, oval or elliptical, in transverse section (Figs. 13 and 14), curves out almost at right angles from the hypocotyl, and extends upwards in the free half of the scutellum in a median plane, nearly to the upper edge (Fig. 10). For a short distance it becomes broader in its progress upwards, but finally divides and spreads out in a fan-like fashion, giving off a number of fine branch strands, each five to ten cells thick. Some seven or eight of these on the right and a similar number on the

left curve round and extend backwards in sinuous lines more or less parallel to each other, a few on each side being continued almost to the base of the scutellum (Fig. 13).

In the young state the cells of the strands are thin-walled, but after germination and growth of the young plant, xylem tracheids, with lignified walls and annular or spiral thickening, are differentiated, and, in addition, a certain proportion of the parenchyma of the scutellum exhibits similar, though less extensive, thickening of most of its cell walls, transverse as well as longitudinal.

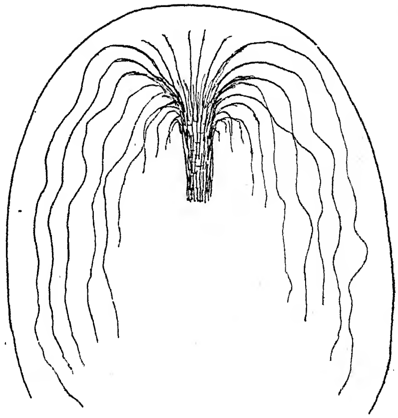


FIG. 13.—Diagram of the bundles of the scutellum.

In the majority of wheats two straight, unbranched bundles traverse the coleoptile from base to apex, one on each side, arranged in a plane almost parallel to the face of the scutellum ; in *T. hermonis* and Indo-Abyssinian forms of *T. dicoccum* two to four additional bundles are present in the outer half of the coleoptile (Fig. 16).

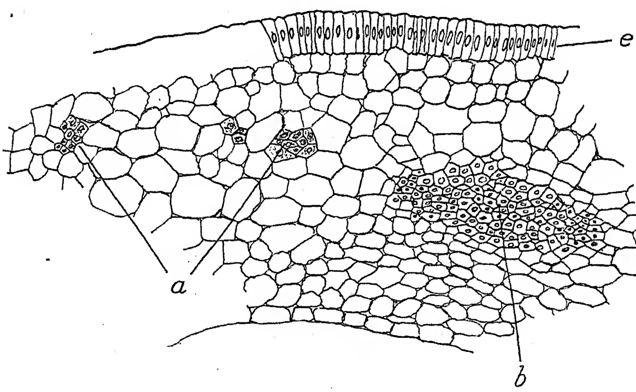


FIG. 14.—Transverse section of portion of scutellum (× 105). *e*, Epithelium ; *b*, section of large central bundle ; *a*, sections of small bundles (cf. Fig. 16).

The rudimentary first green foliage leaf of *T. vulgare* usually possesses eleven bundles, the second leaf seven.

The arrangement and number of the bundles of the scutellum, coleoptile, and first and second foliage leaves are shown in Fig. 15.

Traced downwards, four bundles of the first foliage leaf (two from the right and two from the left of the midrib, Nos. 2, 4, 8, and 10) and

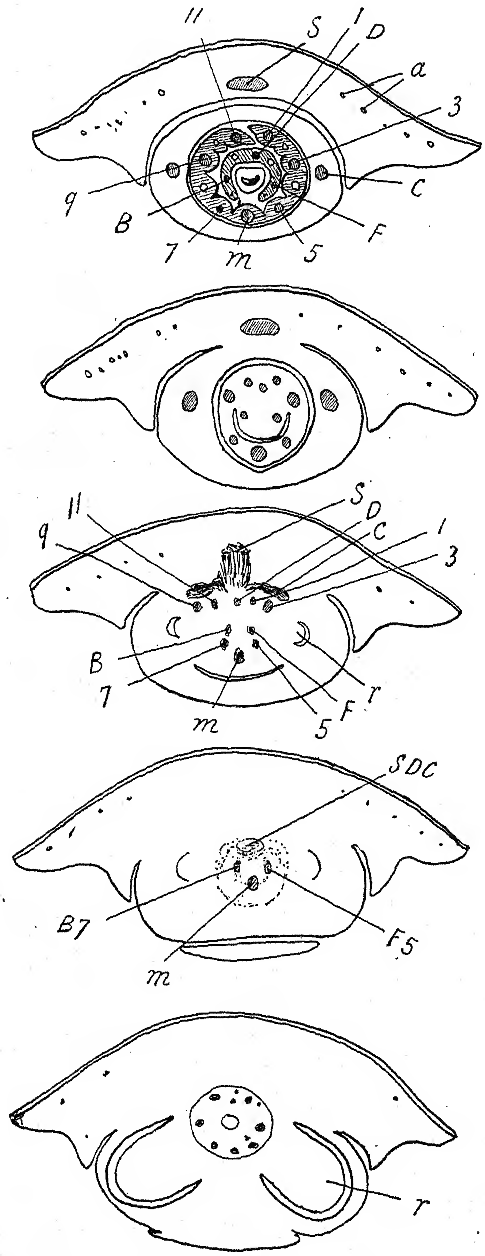


FIG. 15.—Transverse sections of the embryo showing the arrangement and number of the vascular bundles at different levels. *s*, Central bundle of scutellum; *a*, smaller bundles of scutellum; 1-11, bundles of first foliage leaf; *m*, midrib of the same; *B*, *D*, *F*, bundles of second foliage leaf; *r*, lateral roots.

four belonging to the second foliage leaf disappear before the point of insertion of the first foliage leaf is reached.

Lower down, near the point of insertion of the coleoptile, the scutellum bundle divides, the right and left halves joining the bundles from the coleoptile just outside the stele.

Still lower, the bundle 5 from the first foliage leaf coalesces with bundle *B* from the second leaf, and similarly bundles 7 and *F* on the other side of the midrib (6) unite with each other: these all join the vascular elements of the pair of lateral rootlets which arise at this point.

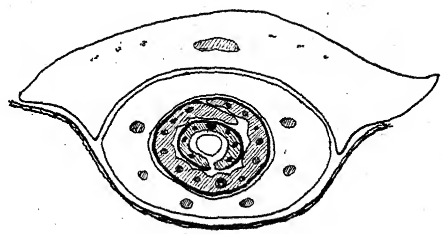


FIG. 16.—Transverse section of the scutellum and plumule of Abyssinian Emmer (*T. dicoccum*). Coleoptile with six vascular bundles.

The midrib bundle 6 appears to pass down through the node into the primary root without combining with others, although the anatomy at the node is obscure.

In regard to the homology of the various parts of the embryo many different views have been advanced. The scutellum is usually considered a cotyledon, although Regel, Hofmeister,

Sachs, and others look upon it as an outgrowth of the hypocotyl or radicle.

The epiblast, according to Bruns and Celakowsky, is a reduced second cotyledon; others suggest that it is a scale-like trichome; to Worsdell it is a part of the cotyledon, and corresponds to the auricles at the base of the blade of a green foliage leaf.

The coleoptile or plumule-sheath is regarded by Hofmeister and Sachs as the true cotyledon, while Van Tieghem, Klebs, and Worsdell describe it as the ligule of the chief cotyledon, the blade of which is the scutellum; to Bruns and others it represents a bladeless leaf, the first of the plumule, the second being the first green foliage leaf of the plant.

The view which I think is most in agreement with the development and structure of the embryo of wheat (see pp. 133-136) is that which regards the scutellum, epiblast, coleoptile, and first green leaf as the first four leaves of the plant. The alternate distichous disposition of these structures on opposite orthostiches also supports this conclusion.

A comparison of the arrangement and relationship of the adventitious roots to the buds and leaves at the "tillering" nodes of the older plant suggests that the three pairs of opposite seminal rootlets of the young wheat plant are associated with three leaves—scutellum, epiblast, and coleoptile—the plane through them being at right angles to the median plane of these reduced leaves, an arrangement similar to that of later roots which spring from the older parts of the axis bearing the foliage leaves (see pp. 36-38).

The rootlet which appears at right angles to the plane of the rest, above the epiblast, suggests the suppression of a bud in the axil of the latter, a corresponding opposite rootlet frequently developing from the base of the axillary bud of the coleoptile.

Colour of the Grain.—One or two Abyssinian varieties of *T. dicoccum* possess grains which are a rich purple tint when freshly ripened, the colour being due to the presence of an anthocyan pigment located chiefly in the chlorophyll or "cross" layer of the pericarp (p. 8).

All other wheats have grains which are usually classified as "white" or "red." The distinction is based on the character of the testa: in "white" wheats the latter is colourless, while in "red" wheats an oily or resinous material develops in the cell lumen and cell walls of its two cell layers during ripening.

The particular shade exhibited by the grain is, however, dependent not only upon the amount of colour in the testa, but upon the thickness, tint, and transparency of the superposed pericarp, and the "mealy" and "flinty" character of the endosperm.

The pericarp is translucent, and in grains ripened in a hot, dry season is a pale creamy tint, like that of clean unweathered straw.

"White" wheats show a range of tint from an opaque creamy-white to a translucent amber or yellowish shade; the former, of which beautiful examples are seen in Australian and some Asiatic wheats, possess "mealy" endosperm, while grains of the amber tint have yellowish "flinty" endosperm which is visible through the thin pericarp.

Among "red" wheats the colour passes by fine gradation from the palest tint to a dark brick-red or brown.

The colour is most readily distinguished in grains with "mealy" endosperm, for the latter provides an opaque chalk-like background, against which the colour of the testa and pericarp are clearly seen.

In many Squarehead forms of wheat with opaque chalky endosperm the grains are an orange tint, a pale red testa being modified by the yellowish-white pericarp: others, especially certain Chinese and Japanese forms with a highly coloured testa and "mealy" endosperm, have rich brick-red grains.

Red grains with "flinty" endosperm are always darker than mealy grains of the same variety.

Where the grain is shrivelled or the pericarp discoloured by exposure to rain or the attack of fungi, its true tint cannot be determined with certainty. There is, however, usually little difficulty in assigning clean, well-grown samples of wheat to their respective "white" or "red" classes, except in certain forms of *T. durum* with translucent flinty endosperm: among the latter wheats, pale "red" grains and amber-tinted examples belonging to the "white" class can only be separated by the most careful examination in a favourable light on a dark background.

"Hard" "flinty" and "Soft" "mealy" Grains.—The endosperm of certain grains of wheat, when cut transversely, is found to be dense and translucent, resembling horn or flint in colour and transparency; to such the terms "flinty," "glassy," "horny," and "steely" have been applied. Flinty grains are comparatively hard, with a somewhat vitreous fracture, breaking into angular fragments, and market samples largely composed of such grains are often designated "hard" wheats.

So-called "soft" wheats have "mealy" or "starchy" grains, possessing a very white, chalky endosperm; the grains are opaque and comparatively soft, yielding a loose mass of floury meal when crushed.

Sometimes the endosperm of a single grain is mealy in one part and flinty in another: in such semi-flinty grains the apical portion is always flinty, the white opaque part being found especially on the dorsal side near the embryo, the mealiness being most conspicuous about the upper edge and back of the scutellum, and extending inwards across the endosperm to the furrow.

In many instances the grains of an ear are either all flinty or all mealy, but not infrequently some ears contain both forms; in the latter cases

I have usually found that the small spikelets near the base and apex bear a greater proportion of mealy grains than the larger spikelets from the middle of the ear, and the lower heavy grains of each spikelet are usually more flinty than the smaller upper ones.

The flinty grains of any pedigree line wheats are, on an average, not only larger and heavier than those of the same sample with mealy endosperm, but have a higher specific gravity than the mealy grains.

Investigations of two examples gave the following results :

Vol. of 100 Grains. c.c.		Weight of 100 Grains. gr.		Sp. Gr.	
Flinty.	Mealy.	Flinty.	Mealy.	Flinty.	Mealy.
3·4 3·7	3·1 3·46	4·54 5·01	4·04 4·48	1·335 1·344	1·287 1·292

The flinty grains in these wheats are usually 7-10 per cent larger, 10-12 per cent heavier, and have a specific gravity 3-4 per cent higher than that of mealy grains.

The white opaque appearance of the endosperm of mealy grains is due to the presence of minute fissures, which develop between and within the cells during the dessication which occurs at the time of ripening of the grain.

On examination of carefully prepared transverse sections[1] from grains showing different degrees of mealiness, it is seen that interstices have formed along the line of union of adjacent cells and around the starch grains within the latter, and the contents of some of the cells have shrunk more or less away from the surrounding cell wall ; these changes appear first near the furrow, and spread radially outwards across the endosperm towards the aleuron layer on the dorsal side, especially in the basal half of the grain near the embryo.

Minute irregular cavities are seen also in the aleuron cells.

From investigations on mealy grains of barley, Brown and Escombe concluded that the interstices are vacuous or only partially filled with air.

Such minute spaces are absent from flinty endosperm in which all the cells of the tissue are completely filled with starch grains imbedded in a protoplasmic matrix, the whole forming a dense coherent mass.

The production of flinty or mealy grains is a hereditary character of

[1] The endosperm of uninjured flinty grains appears to be under a stress which tends to rupture the cells and cell contents, and thin sections cut from flinty grains immediately become opaque and "mealy." To obtain sections sufficiently thin to be examined with a high power, without disturbing the original physical condition of the endosperm, thick dry sections may be ground down on a " carborundum " stone with the finger-tip. Examine the sections in oil or Canada balsam.

particular races and forms of wheat. The grains of *T. aegilopoides*, *T. dicoccoides*, *T. monococcum*, and *T. durum* are almost always flinty, while those of *T. turgidum* and many forms of *T. vulgare* and *T. compactum* are especially mealy.

Mealy grains are most commonly developed among those races and forms whose individual spikelets bear the greatest number of grains, and there is strong positive correlation between mealiness and high grain-yielding capacity in the race of Bread wheats (*T. vulgare*). Varieties possessing normally opaque grains are generally slow-growing wheats with a long vegetative period and adapted for cultivation in humid climates or on irrigated land. On the other hand, those giving a high proportion of flinty grains produce less, grow and ripen more rapidly, and are met with chiefly in regions having a comparatively dry continental climate.

While some wheats maintain their distinctive type of endosperm under widely different circumstances, others can be made to yield flinty or mealy grains by varying the nutrition and the external conditions of growth of the plant.

The Macaroni wheats (*T. durum*) have the most typically flinty grains, and in these the feature is so strongly inherent that it is rarely or never changed by environment.

In the opposite class are the Rivet wheats (*T. turgidum*), whose grains are generally opaque and mealy; in these the character is also comparatively stable, and only with difficulty are some of them induced to bear ripe, flinty grain.

The Bread wheats (*T. vulgare*) are very variable in regard to the physical appearance of the endosperm. While some of them exhibit a strong hereditary tendency to bear grains with flinty or mealy endosperm, the character is much less rigidly established in this race, and in many forms of it the production of hard, translucent, or soft, opaque grains is determined by climate and soil.

Among wheats commonly cultivated in this country the flinty grains of a sample when sown give rise to plants yielding either flinty or mealy grains according to the season, the texture of the soil, the space allotted to the plants, or their manurial treatment; mealy grains behave in a similar manner, the physical nature of the endosperm being in both cases controlled by environment.

Wheats grown in cool districts with abundant rainfall or under irrigation have softer and more mealy grains than those cultivated in drier and warmer regions.

Voelcker's investigations at Woburn show that heavy soils have a tendency to produce flinty grains, while light sandy loams give a higher proportion of mealy grains, these effects being independent of the flinty or mealy nature of the grain sown.

In the following table are given the results obtained from pot cultures at Woburn in 1900:

Grain sown.	Produce.		
	Mealy Grain.	Flinty Grain.	½ Mealy Grain.
	per cent.	per cent.	per cent.
Mealy grains in light soil—			
Pot 1	100	..	..
Pot 2	47·7	6·9	45·4
Pot 3	84·9	15·1	..
Flinty grains in light soil—			
Pot 1	95·2	4·8	..
Pot 2	79·4	20·6	..
Pot 3	64·7	16·3	19·0
Mealy grains in heavy soil	..	100	..
Flinty grains in heavy soil	..	100	..

Plants allowed plenty of space always yield a higher proportion of flinty grains than those which are closely crowded; below is given the percentage of mealy and flinty grains in a *vulgare* wheat, grown at various intervals in rows from 6 inches to 24 inches apart; generally in samples of the same wheat produced under ordinary field culture 90 per cent of the grains are mealy or half-mealy.

"SWAN" WHEAT

PERCENTAGE OF FLINTY, HALF-MEALY, AND MEALY GRAINS

	Area allotted to each Plant.					
	Inches. 6 × 1.	Inches. 6 × 3.	Inches. 6 × 6.	Inches. 12 × 6.	Inches. 12 × 12.	Inches. 24 × 24.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Mealy	9·5	10·1	6·4	3·7	3·2	·2
Half-mealy	22·2	12·7	3·8	2·6	3·3	1·2
Flinty	68·3	77·2	89·8	93·7	93·5	98·6

Although the translucency or opacity of the endosperm is a physical phenomenon it is correlated with the amount of nitrogen present, the flinty grains being always richer in this element than the mealy grains of the same sample.

Moreover, flintiness can be induced in any form of *T. vulgare* by application of large amounts of nitrate of soda or sulphate of ammonia.

At the University College Farm, Reading, these fertilisers were applied to small plots of wheat for several years at the rate of 1, 2, 4, 8, and 16 cwts. per acre respectively; comparison of the produce with that from the unmanured plots showed that 1 cwt. per acre distinctly increased the percentage of flinty grains in *T. vulgare*, and the higher amounts led to the whole of the sample being flinty.

In the case of the soft floury Blue Cone wheat (*T. turgidum*) it was not until an application of 4 cwt. or more per acre was given that the mealy nature of the endosperm was modified, and only when 8 to 16 cwt. per acre was used were all the grains flinty.

Similar graduated quantities of the ordinary phosphatic and potassic fertilisers were tried, but none of these increased the flintiness of the endosperm.

Forms which ordinarily produce mealy grains only do so under conditions which allow of complete development and normal ripening, for the grains of all wheats harvested in an immature state have flinty endosperm. The results of harvesting two mealy-grained forms of *T. vulgare* at weekly intervals are given below; they illustrate the progressive increase in the percentage of soft opaque grains up to the time of perfect ripeness.

"SQUAREHEAD'S MASTER" WHEAT

PERCENTAGE OF FLINTY AND MEALY GRAINS IN EARS CUT AT WEEKLY INTERVALS UNTIL RIPE.

1914.	Mealy.	Flinty.	Average weight of 100 Grains. (Air-dry.)
			gr.
July 4	0	100	1·42
,, 11	0	100	2·70
,, 18	34	66	4·08
,, 25	54	46	4·95
Aug. 1	89	11	5·01
,, 8	89	11	4·81

"SWAN" WHEAT

1916.	Mealy.	Flinty.	Average weight of 100 Grains. (Air-dry.)
			gr.
July 7	0	100	·77
,, 14	0	100	1·54
,, 21	0	100	2·48
,, 28	37	63	3·46
Aug. 4	77	23	4·67
,, 11	96	4	4·67
,, 18	96	4	4·51

"Strong" and "Weak" Wheats.—The miller and baker usually grade the Bread wheats and the flour obtained from them into "strong" and "weak" varieties, the term "strong" being applied to those wheats whose flour makes large uniformly porous loaves, the "weak" flour producing smaller denser loaves.

Although there are many exceptions, the "strong" wheats generally have red grains with hard "flinty" endosperm, the weaker types having paler red or white grains with opaque "chalky" endosperm.

CHAPTER III

GERMINATION OF THE GRAIN

A NORMALLY ripened wheat grain, sown an inch or an inch and a half deep in good soil, early in September, begins to germinate in two or three days, the coleoptile and first leaf appearing above ground in about ten days. The grain which at the time of ripening became comparatively dry now absorbs water from the ground, and the dormant embryo soon gives signs of growth. Concurrent with the visible morphological changes in the embryo, changes occur in the reserve materials stored in the endosperm, the solid proteins and carbohydrates of the latter being rendered soluble and diffusible by the action of various enzymes.

Before germination can proceed a number of conditions must be fulfilled, the chief of which are: (1) a suitable degree of moisture of the seed-bed, (2) an adequate temperature, and (3) a sufficiency of oxygen. A deficiency of water, heat, or fresh air retards or completely prevents germination.

A grain which is on the point of germinating is swollen, its volume compared with that of a dry caryopsis being considerably increased by the water which it has absorbed. The puckered surface of the pericarp covering the embryo becomes smoother, and the whole wall of the fruit is tense.

Very soon the growing embryo bursts its covering near the base of the grain, the first portion to emerge being the dilated coleorhiza, which expands at first in a transverse direction, and tears a longitudinal slit in the pericarp, thus exposing the plumule. Just after its escape it appears as a short truncate structure, falsely suggesting the presence of two rootlets within it (Fig. 17), and consists of elongated and distended parenchymatous cells between which are many intercellular spaces which give the tissue a white glistening appearance. Later, a number of long unicellular hairs, resembling root-hairs in form and function, often arise from the cells of the coleorhiza, especially near its base.

After the coleorhiza has grown about a millimetre, the enclosed primary root bores through it, usually on one side, leaving a bulging

angular portion opposite. An hour or two later the first pair of lateral rootlets become visible, each with its thin covering root-sheath; these spring from the sides of the short hypocotyl almost in line with the base of the epiblast (Fig. 18).

Under favourable conditions the three rootlets and plumule grow

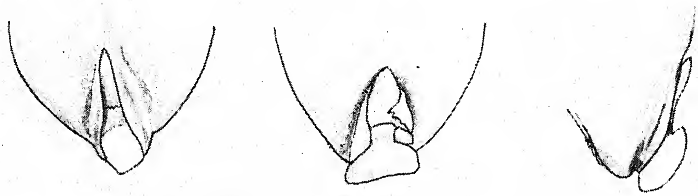


FIG. 17.—Base of germinating grains, showing rupture of the pericarp by the coleorhiza and plumule of the growing embryo.

rapidly, the former elongating much more quickly than the latter. The primary root is for a time somewhat longer than the secondary ones, but later there is little difference between them either in length or thickness. Usually in three or four days, when the first rootlets have attained a length of about 2 cm., two more appear, one on each side of the hypocotyl imme-

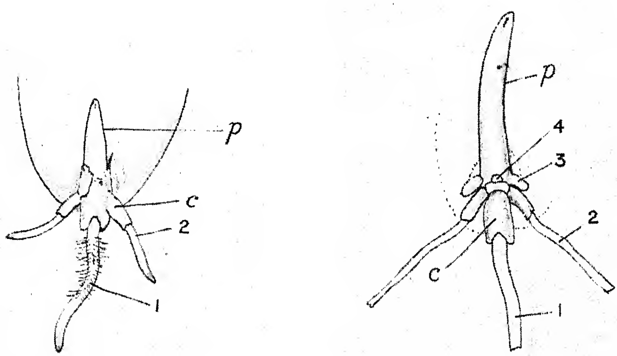


FIG. 18.—Young plants. *p*, Plumule; *c*, coleorhiza; 1, primary root; 2, root of first pair of lateral roots; 3, root of second pair; 4, root above the epiblast, inserted at right angles to the others.

diately above the first pair, a sixth rootlet sometimes developing later, at right angles to the rest, from a point on the axis behind the epiblast (Fig. 18).

The germination of the naked caryopses of *T. monococcum*, *T. dicoccum*, and *T. Spelta* is similar to that of other wheats: sprouting is, however,

generally more speedy in these grains on account of the thinner pericarp, which permits of rapid absorption of water.

When whole spikelets of the "Spelt" wheats are sown, the coleorhiza and rootlets of the embryo pierce the base of the grain and the enclosing flowering glume, but are unable to break through the thicker empty glumes, the entrance of the rootlet into the ground being made past the edges of the latter at the base of the spikelet.

In these wheats, in which strong glumes closely invest the grain, no longitudinal slit exposing the plumule is torn in the pericarp by the expanding coleorhiza and rootlet.

In some cases the flattened wedge-like coleoptile breaks through the pericarp near the upper edge of the scutellum and appears at the tip of the spikelet, after growing along the space between the outer surface of the caryopsis and the inner surface of the flowering glume: most frequently, however, the plumule escapes from the apex of the grain after pushing its way longitudinally within the substance of the pericarp in which it travels through the thin parenchyma outside the "cross layer."

Placed in the soil or on damp filter paper, wheat caryopses soon begin to absorb water, which penetrates most rapidly through the thin portion of the pericarp covering the embryo. Laid furrow side down on a wet surface, they imbibe more slowly than when the dorsal half is wetted.

In order to test the amount absorbed, 100 grains were completely immersed in water. At certain intervals they were withdrawn, and after the superfluous water had been carefully removed from their surfaces by means of filter paper, were weighed again. They were then immersed for a further period. The results obtained are shown in the table on the following page.

Germination commenced after about 40 hours' immersion, up to which time the amount of water absorbed by the grains steadily increased, the flinty grains imbibing more slowly than the starchy ones.

From another series of investigations I found that grains do not sprout until they have absorbed at least 30 per cent of their weight of water, and, with the water content maintained at this figure, germination is feeble and protracted.

The coleorhiza emerges in about 24 hours after the grains have taken up 35 per cent of water, which they usually do after 12 to 14 hours' soaking at 17-18° C. The most vigorous germination, however, at this temperature takes place when the amount imbibed is 36-40 per cent of the air-dry weight of the grains.

In addition to the increased weight due to the absorption of water, there is always a change in the volume of the grain, the swollen caryopsis ready to germinate being from 35 to 40 per cent larger than when air-dry.

"SWAN" WHEAT

Temperature 16° C.

	Weight.	Increase.	Percentage Increase.
	grs.	grs.	
100 starchy grains air-dry	4·70	..	..
Weight after soaking 30 minutes	5·14	·44	9·4
,, ,, 1 hour	5·33	·63	13·4
,, ,, 3 hours	5·44	·74	15·7
,, ,, 6 ,,	5·64	·94	20·0
,, ,, 9 ,,	5·84	1·14	24·2
,, ,, 28 ,,	6·45	1·75	37·2
,, ,, 36 ,,	6·68	1·98	42·1
,, ,, 53 ,,	6·77	2·07	44·0
100 flinty grains air-dry	4·98	..	..
Weight after soaking 3 hours	5·64	·66	13·2
,, ,, 6 ,,	5·81	·83	16·6
,, ,, 9 ,,	5·98	1·00	20·1
,, ,, 28 ,,	6·49	1·51	30·3
,, ,, 36 ,,	6·73	1·75	35·1
,, ,, 53 ,,	6·93	1·95	39·1

The relative volumes and weights of the grain when dry, and the same after soaking 5 hours and 28 hours respectively, were found in one trial to be:

	Air-dry.	After soaking.	
		5 Hours.	28 Hours.
Relative volume	1	1·222	1·416
Relative weight	1	1·190	1·366

The increase in volume is somewhat greater than the addition in weight, an augmentation of the latter of 19 and 36·6 per cent respectively being attended by a rise in volume of 22·2 and 41·6 per cent.

The optimum temperature, at which germination is most rapid lies between 20° and 22° C., the minimum, below which it is completely checked, is about 4° C. The influence of different temperature is seen in the following results obtained with a Squarehead form of wheat harvested in August and tested in November 1914.

PERCENTAGE GERMINATION

After	35° C.	22° C.	16° C.	12° C.	8° C.
24 hours	33	63	10	0	0
48 "	51	32	67	0	0
72 "	9	5	22	99	14
96 "	4	..	..	..	37
120 "	1	..	..	..	43
144 "	2	..	..	..	6
	100	100	99	99	100

At temperatures considerably above the optimum the grains germinate irregularly, the sprouting of some of them being much delayed. Moreover, the embryos frequently die or become so much weakened that they are liable to be destroyed by the attacks of fungi and bacteria; the endosperm also often undergoes decomposition through the activity of these organisms when the moist grains are kept at 35° C. or higher.

Although germination begins in two or three days or less in grain sown in the open field at any period of the year, the progress made by the growing embryo is very slow in late autumn and winter when the temperature is low, especially if at the same season the rainfall is excessive. The time which elapses before the coleoptile appears above ground in grains deposited at a depth of an inch may vary between one and ten weeks.

Observations made upon weekly sowings of wheat during 1912, 1913, and 1914 gave the following results, the grains being sown at a depth of one inch:

NUMBER OF DAYS BETWEEN THE TIME OF SOWING AND THE APPEARANCE OF THE YOUNG PLANT ABOVE GROUND IN WHEAT SOWN IN DIFFERENT MONTHS OF THE YEAR.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912	..	16	9	6	7	7	7	8	10	17	39	71
1913	50	..	23	15	8	9	14	12	10	11	21	42
1914	35	31	22	9	8	7	..	..	..	..	..	..

During germination extensive chemical changes occur both in the embryo and the reserve materials of the endosperm.

Starch is absent from the tissues of the dormant embryo except in the merest traces, but minute globules of a fatty oil and small spherical aleuron

grains—granules of protein, each possessing one or more excessive minute globoids—are present in the parenchyma of the scutellum and oth parts of the embryo.

Before germination begins, the columnar epithelium of the scutellu is devoid of starch, but its cells contain dense cytoplasm and an ov nucleus, which usually rests in the lower half of the cell with its long ax arranged lengthwise in the cell lumen.

In 12 to 16 hours after germination commences in grains sprouti indoors at 18°-20° C. starch granules make their appearance in the ce of the coleorhiza, root-cap, and tip of the coleoptile ; these are deriv chiefly from fat globules or from a soluble carbohydrate stored in t tissues of the embryo and not from the endosperm, since they arise portions of the embryo which have been cut from dry grains and laid up damp filter paper. Nevertheless, dissolved reserves soon begin to l transferred from the endosperm to the growing embryo, and in 24 to hours fine-grained starch is found in the epithelium of the scutellur and in greater abundance in the parenchyma of the latter. Increa ing quantities are seen also about this period in the fully develop cells of the root-cap, in the coleoptile, especially near its apex, and in t coleorhiza ; a small amount is present in the endodermis of the prima root.

The grains are usually spherical, about 1 μ in diameter, and ma of them compound, consisting of two or three partial granules. Th special accumulation in the root-cap and apical cells of the coleopti supports the view of Haberlandt and Němec that they act as statolit in the geotropic curvatures of these parts.

The reserves stored in the endosperm are rendered soluble by vario enzymes. Among the latter, whose presence has been established germinating cereal grains, are cytase and the amyloclastic enzyme diastas presumably, proteoclastic ferments capable of breaking down the reser proteins also occur in the grain, but these have not been investigat in wheat.

The dissolved plastic materials are absorbed by the column epithelium, and passed on through the parenchyma and the vascul system of the scutellum to the growing regions of the young plant.

In the resting state of the embryo the cylindrical epithelial cells a from 30 to 40 μ long with somewhat rectangular ends and dense prot plasmic contents. As germination advances, the cells elongate until th are 80-90 μ long, when absorption is most active, their tips, at the san time, becoming swollen, club-shaped, and separate from each othe projecting into the endosperm (Fig. 19). The vascular strands pe meating the scutellum become more highly differentiated, and many the walls of the scutellar parenchyma thickened and pitted.

In addition to its absorptive function, the epithelium secretes diastase which is responsible for the conversion of the reserve starch grains into the soluble and diffusible maltose. The aleuron cells also secrete diastase, but to a smaller extent, and according to Grüss, Puriewitsch, and others a certain amount of the enzyme is present in the amyliferous cells of the endosperm.

The first visible action of diastase is seen in the starch grains of the endosperm behind the upper part of the scutellum after two or three days of germination at 16° C. Small central slit-like cavities and radiating cracks first appear in the starch grains; these rapidly enlarge, and

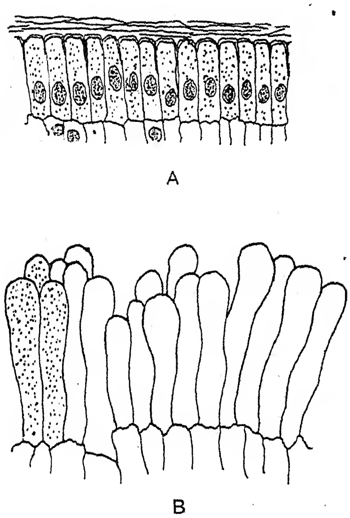


FIG. 19.—Columnar epithelium of the scutellum. A, In a dormant grain; B, in a germinating grain (×275).

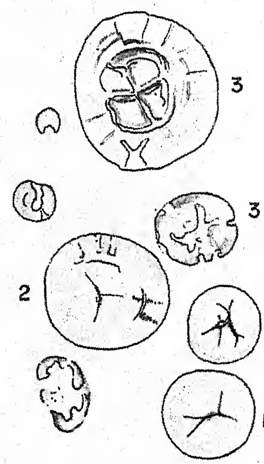


FIG. 20.—Starch grains in various stages of dissolution. 1 and 2, From a grain after 5-7 days' germination; 3, from a grain almost depleted of its endosperm (×575).

dissolution proceeds also along the concentric lines of stratification. In eight or ten days pits and channels are seen; these commence on the outside and penetrate into the interior of the grain, its circular outline being thus broken at various points; the grains are subsequently eroded into irregular fragments, which ultimately dissolve and disappear altogether (Fig. 20).

Concurrent with the starch hydrolysis are modifications in the reserve proteins of the endosperm. The protoplasmic matrix in which the starch grains are imbedded expands after imbibing water, and changes into a hyaline glutinous mass capable of being drawn out into long thin sticky threads; later, it loses its elastic quality and is broken down into simpler

soluble nitrogenous compounds, which are absorbed by the growing embryo with the rest of the soluble plastic materials.

An examination of germinating wheat from day to day shows that the dissolution of the reserves begins in the amyliferous parenchyma behind the upper part of the embryo, and spreads gradually towards the apex of the grain beneath the aleuron layer on the dorsal side, extending also round the flanks towards the ventral furrow.

Rapid action of the enzymes is promoted by the early hydrolysis of the cell membranes of the endosperm by cytase, which, according to the researches of Brown and Escombe and others, is secreted by the aleuron cells. After the destruction of the cell walls, simple, instead of osmotic, diffusion is established, and the starch and other cell contents are exposed to the uninterrupted action of the various enzymes present.

Cytohydrolysis commences very soon after germination begins. In twenty-four hours, or less, the middle lamella of the starch cells in contact with the aleuron layer shows signs of dissolution, and in two or three days the walls of these cells swell and separate from each other, dissolving later and setting free their contents.

The endosperm tissue is gradually converted from the outside inwards into a white pasty mass, which becomes more and more liquid and limpid as the starch grains dissolve, the last portions to disappear being the amyliferous parenchyma around the furrow of the grain and the aleuron cells. Leakage of dissolved reserves is effectively prevented by the semi-permeable testa, which with the cross layer of the pericarp closely overlaps the edges of the scutellum. The aleuron layer, according to Haberlandt, is a glandular digestive organ secreting cytase and diastase, and, according to Bolland, a gluten-transforming ferment also. The protein granules stored within its cells are utilised in the nutrition of the protoplasts of the cells.

The layer undergoes chemical changes more slowly than the rest of the endosperm, little alteration in it being apparent during the first two or three days except its separation from the adjacent starch cells.

In about a week, when the plumule has attained a length of 3 or 4 cm., the aleuron granules in many of the cells have lost their refractive character or have completely disappeared; later, they vanish from all the cells and the remaining brownish granular cytoplasm shrinks and dies, retreating first from the free walls next the endosperm cavity.

The cell walls from which the cytoplasm has shrunk become crumpled, and are soon attacked by the cytase, the cell cavities being then exposed (Fig. 21). Ultimately, the radial and outer walls of the aleuron layer are broken down and dissolved together with the hyaline nucellar layer. In 10-15 days at 18°-20° C., when the first foliage leaf of the young plant is expanded, the pericarp with the adherent testa is found as a hollow

skin within which remains only a watery solution of the last dissolved reserves; the plant has become independent of the parental store and is capable of manufacturing its own plastic materials.

The same sequence of events as that described above is observed in the germination of grain sown in autumn in the open field, but enzyme action and growth are less rapid, owing to the lower temperature at this season. Grains sown during the last few days of October (1914) had their first green leaves completely unfolded in three or four weeks, and at the end of November the endosperm had completely disappeared from the majority of them.

The vitality of the wheat grain and the possibility of its germination capacity being retained for long periods has been the subject of much controversy.

Wheat grains of great antiquity have been unearthed from ancient

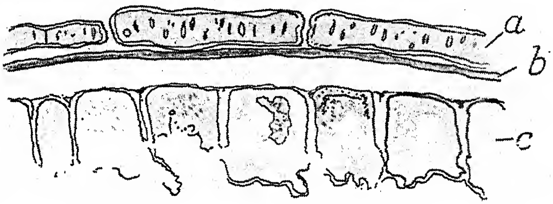


FIG. 21.—Section of a portion of the pericarp and aleuron layer of a grain 16 days from beginning of germination. *a*, Cross layer of pericarp; *b*, testa; *c*, aleuron layer (× 275).

stores and tombs in different parts of the world. In many cases they are completely carbonised, and in this state are merely friable masses of charcoal with the form of the grain: such are those obtained from the neolithic pile-dwellings of Switzerland and the pre-Roman settlements of this country. Specimens from vases deposited in the tombs of ancient Egypt, where they have been kept dry, away from atmospheric changes, show much less alteration, and, except that they are a dark reddish-brown colour as if scorched, appear normal in size and shape.

I examined a number found by Professor Flinders Petrie in the Graeco-Roman cemetery at Hawara (about first century B.C.). These were plump, and similar to some forms of *T. durum* grown at the present day. The pericarp was a dark reddish-brown tint, its structure unchanged. The aleuron layer had retained its original shape, with normal cell walls and typical round aleuron grains within.

The parenchyma of the endosperm contained unaltered starch grains which stained a purple colour with iodine, but the delicate cell walls of

the tissue had disappeared and the masses of starch grains in each cell clung together, preserving the form of the cell-cavity.

The endosperm was very brittle and strongly acid, the acidity being apparently due to decomposition of the proteins of the grain, for these were completely altered and no longer gave rise to gluten when water was added to the finely broken grain.

The embryo had become dark brown, its plumule greatly shrivelled, and little of its structure was visible, although the scutellum with its epithelial cells could be recognised in some of the grains.

In grains from spikelets of Emmer from a tomb of the eighteenth dynasty (1400 B.C., see p. 187) the structure of the pericarp, aleuron layer and its contents, and the endosperm tissue with its starch grains were clearly recognisable, although all the parts were more brittle and the embryo more completely disorganised than in the grains from Hawara. It is scarcely necessary to observe that the embryos were dead.

Professor Petrie tested samples of grain of Graeco-Roman age which he found at Hawara immediately after exhumation. The grains were sown on the banks of a canal in soil of varying degrees of moisture from mud to fairly dry earth, but none germinated.

From time to time, however, during the last century, reports have been given of the germination of grains taken from Egyptian tombs, but the evidence when tested is invariably unsatisfactory.

In some cases it is clear that modern grain has been inadvertently admitted to mummy cases, the wrappings of mummies, and vessels taken from tombs. Sometimes imperfectly thrashed straw and even chaff with grain have been used as packing for mummies, and mummy cases and tombs have been used in modern times as convenient stores for grain.

Modern wheat grains appropriately stained have sometimes been fraudulently mixed with wheat taken from ancient vases, the whole being sold to the credulous tourist as "mummy wheat," or introduced into mummy cases, or placed within the wrappings of mummies.

Genuine vases apparently unopened but containing such grain are also occasionally sold to travellers.

In regard to recent samples of wheat grains, the duration of their vitality is dependent chiefly upon (1) the degree of ripeness and the water-content of the grain at harvest, and (2) the temperature and moisture of the place of storage.

Poorly developed grain, and grain with a high percentage of water in it, loses its capacity for germination in a year or two, while well-ripened dry samples retain their vitality for several years.

Storage in a warm room, especially if the atmosphere is damp, leads to rapid death of the embryo.

Many tests have been made with grains of wheat whose age is beyond

dispute. These have shown that when kept in an ordinary dry room grains lose their vitality altogether or have their germinating capacity greatly reduced in ten years or less.

The rate of loss of vitality is shown in the following records by Burgerstein, Carruthers, and Gross:

PERCENTAGE GERMINATION

	Age of Seed—Years.									
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Burgerstein	100	98	95	94	87	87	85	79	70	75
Carruthers	100	97	92	94	?	88	75	?	29	0
Gross	100	100	94	95	95	76	72	46	15	6

The grains used by Gross had been stored in open glass beakers or small bags in a dry unheated room.

In 1907 I tested samples of grain grown on the farmyard manure plot at Rothamsted. These had been artificially dried after harvest before being stored in glass bottles.

The following results were obtained:

PERCENTAGE GERMINATION

Year of Harvest

1906.	1905.	1904.	1903.	1902.	1901.	1900.	1899.	1898.
94	74	3	80	40	99	74	99	38
1897.	1896.	1895.	1894.	1893.	1892.	1891.	1890.	1889.
0	67	57	45	57	29	0	0	0
1888.	1887.	1886.	1885.	1884.	1883.	1882.	1881.	1880.
0	0	18	0	1	0	16	0	0

Some of the grains of the harvest of 1882 had retained their vitality for twenty-five years.

CHAPTER IV

THE ROOTS

General Morphology

The roots of the wheat plant may be divided into two groups, namely, (1) the seminal roots, or those belonging initially to the embryo, or which develop later from the hypocotyl or near it, and (2) the adventitious roots, which spring from the nodes of the plant, within the soil or just above it.

As previously mentioned, the embryo possesses five roots, namely, a primary radicle and two pairs of lateral rootlets, which originate from the hypocotyl in a plane parallel to the face of the scutellum ; a sixth is often produced later from a point just behind the epiblast at the base of the plumule, and grows out at right angles to the plane in which the others are found (4, Fig. 18 ; *n*, Fig. 22).

The primary radicle and the first pair of seminal rootlets burst through the tissue of the coleorhiza soon after germination commences, these being followed subsequently by a second pair ; the sixth rootlet, if it appears at all, does so only after the others have attained a considerable length when growth is more advanced. A third pair appears immediately above the second pair and in the same plane, making in all eight seminal roots.

The apex of each root is pointed, smooth, and more or less mucilaginous. The growing point is protected by the root-cap, the outside of which is continually being exfoliated as the tip of the root is forced through the soil, and as rapidly renewed on the inside by the activity of its meristem.

The surface of the rootlet for some distance behind the apex is clothed with extremely delicate root-hairs.

As the root increases in length and penetrates into fresh regions of the soil, new root-hairs arise at a short distance from the tip, while those on the older portions of the root, after collapsing, lose their absorptive power and turn brown and die. The number of root-hairs is extraordinarily large ; from 700 to 1000 or more per millimetre length of root are found in the region of most active absorption.

A number of hairs similar in form and function to root-hairs often

arise on the basal portions of the coleorhiza soon after the primary root has broken through it.

The seminal roots are all thin and of nearly uniform diameter throughout their length; when turgid and growing they measure from ·5 to ·75 mm. across; later, when the soft cortical tissues are shrivelled, they may become less than half this thickness.

Numbers of very delicate lateral branches, often not more than a tenth of a millimetre in diameter, appear on the rootlets, generally as soon as these have reached a length of 4 to 6 inches.

The seminal roots form but a small proportion of the total root-system of the wheat plant, their function being concerned with the absorption of the water necessary for the growth of the young plant, especially in its early stages of development, although they appear to be functional throughout the life of the plant, for they remain undecayed up to near the time of harvest. The extent of their development and the depth to which they descend is influenced by the texture of the soil and the depth at which the grain is sown. Where the latter is deposited near the surface, the seminal roots reach their maximum development and penetrate to a depth of 8-12 inches or more; where the grain is sown at greater depths they grow feebly, the reserves of the endosperm being chiefly utilised in enabling the shoot to grow and reach the light above ground (Fig. 60).

The adventitious roots arise just near the surface of the ground from the nodes of the main axis and its branches, their position being correlated with the arrangement of the buds and leaves of the plant. The first to appear is a pair of roots which grow out from the tillering node of the primary axis (Figs. 22 and 23), one of them on the right, the other on the left of the first lateral bud, their points of origin being not quite on the same level. One of them appears before the other, and in its rapid growth tends to push aside the adjacent bud from the initial position; especially does this happen when the opposite root fails to develop.

At the second node another pair develops in like manner, and from each of the succeeding somewhat thicker nodes, between which the internodes remain short, two roots appear arranged similarly in regard to the nodal bud together with one or more on the opposite side to that on which the bud arises. Of each pair, the first root to develop is always found on the same orthostich of the stem.

At the base of the straws near the ground, where the internodes are longer and the nodes, therefore, not so crowded together, four or six roots are produced at each node, *i.e.* two or three pairs symmetrically arranged as in Fig. 24; the upper series of these usually form very strong oblique props which assist in keeping the straw erect.

Longitudinal planes through the points of origin of opposite adventitious roots of the primary axis cut the plane through the buds and midribs

of the leaves of the axis at right angles, and are parallel to the plane in which the three pairs of seminal rootlets are found.

The second and succeeding axes or shoots develop their own independent system of adventitious roots, which follow the same general arrangement in pairs as that of the primary stem, except that at the base of each bud or axis of the second and subsequent order, a single root first appears. Moreover the roots on one axis are always arranged in a longitudinal plane at right angles to that which includes the roots on the axis of the previous order. The longitudinal plane through the roots of the first lateral shoot at the tillering node cuts the plane of the roots of the primary axis at right angles; the sixth seminal root, which springs from a point just above the epiblast, is in this plane (*n*, Fig. 22).

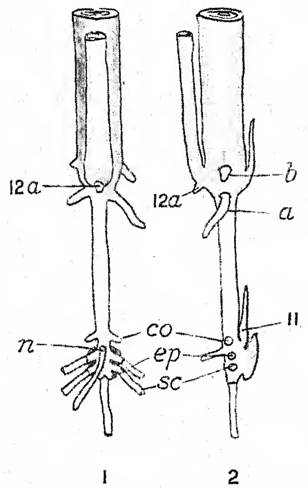


FIG. 22.—Arrangement of the seminal roots and the adventitious roots at the "tillering" node of a young plant. *sc*, Scutellum pair; *ep*, epiblast pair; *co*, coleoptile pair; *a*, one of the pair of roots at first node of primary stem; *b*, one of pair at second node of primary stem; 11, first branch of primary axis; 12*a*, one of pair of roots at first node of second branch of primary axis.

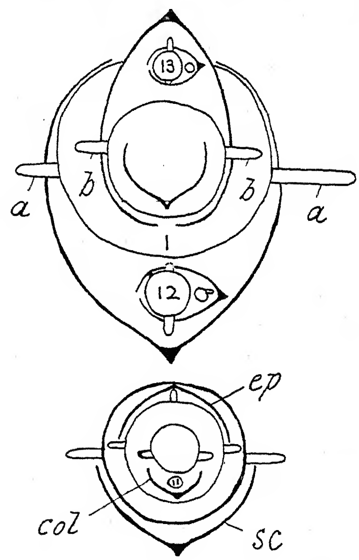


FIG. 23.—Diagram of the arrangement of the roots, stem axes, and leaves in the previous figure.

The adventitious roots do not begin to appear until long after the leaves of the first or second buds have come above ground. In crops sown in October and November, particularly when the autumn is wet, their production is usually delayed until the end of the following January, at which date the first pair at the tillering node is often not more than half an inch long: after this date they develop more rapidly. Generally about the first or second week in March the first roots at the base of the

lateral axes appear, four or five roots being usually present at this time at the tillering node, the longest being about 3 inches, the shortest about $1\frac{1}{2}$ inches long, the primary shoot then showing 4 or 5 leaf-blades, the two secondary shoots 3 or 4 blades each. For a considerable period these roots are unbranched, and clothed throughout their entire length except the tip by root-hairs. Later, numerous branches appear, after which time the piliferous layer shrivels and the roots become thinner and brown. New roots continue to break out from the nodes of the straws until May or June, by which time an extensive system has been established in plants which are not crowded. All these adventitious roots are of greater length and thickness than the seminal roots; some, which spring from near the base of the straws, are 1·5-2 mm. in diameter, and ultimately become very rigid in the first inch or so of their lengths; in the

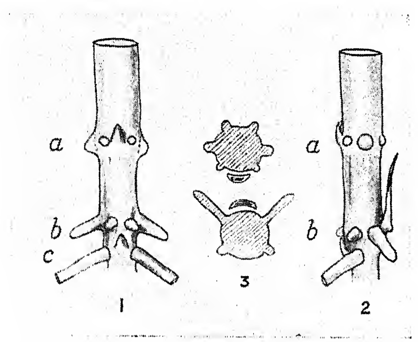


FIG. 24.—Arrangement of the adventitious roots at the three basal nodes of a culm (×1·5). 1, Front; 2, side view; 3, transverse sections at *a* and *b*.

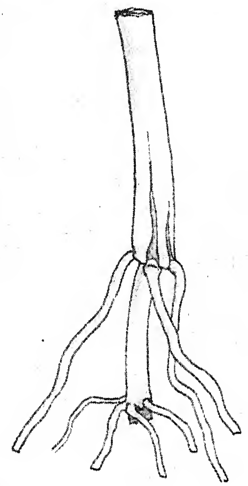


FIG. 25.—"Anchoring" roots at the base of a culm (nat. size).

parts exposed to the air, chloroplasts are present in their cortical tissues (*c*, Fig. 30). About 60 per cent of the roots are found in the upper 8-12 inches of the soil, the rest extend to greater depths, a few occasionally penetrating 4 or 5 feet or more, especially in deep loams.

The root-system of thin-strawed varieties with upright young shoots is less extensive than that of thick-strawed forms with a spreading habit when young.

Moreover, the roots of wheats with erect young shoots are thin and spread very little near the surface of the soil; plants with roots of this habit are easily laid by wind and rain.

The roots of the varieties with young spreading shoots are stout; they also make a wide angle with the vertical and anchor the plant firmly to the soil, isolated and normally grown plants of these varieties being never laid by wind or rain.

ANATOMY OF THE ROOTS

In a transverse section through a young seminal root about a centimetre from its apex the following tissues are readily recognised: (1) an outer piliferous layer, (2) a broad zone of cortex limited internally by a well-defined endodermis, and (3) a polyarch central vascular cylinder with its surrounding pericycle (Figs. 26, 27).

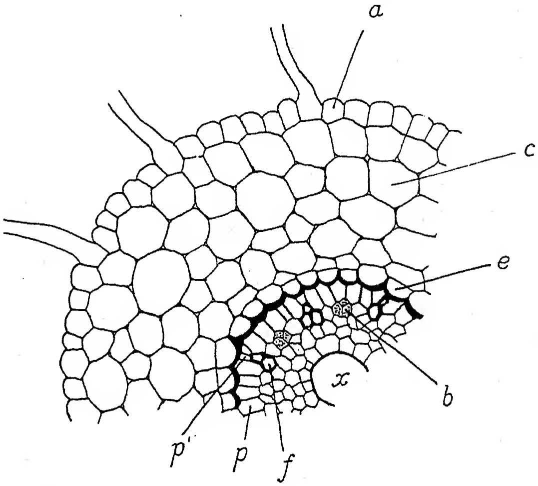


FIG. 26.—Transverse section of a seminal root (× 100). *a*, Piliferous layer; *c*, cortex; *e*, endodermis; *p*, pericycle; *p'* small cells of pericycle opposite protoxylem; *f*, protoxylem; *b*, phloem; *x*, large central vessel.

The piliferous layer consists of thin-walled elongated cells usually from 170 to 350 μ long and 25-30 μ in diameter. From many of these are developed root-hairs which are produced by the bulging out and growth of a small portion of the cell wall, the point of origin in each case being usually between the middle and the transverse septum nearest the root-tip. These hairs first appear as very short papillae about 1·5 to 2 millimetres behind the apex of the root: further back, where fully developed, they are seen to be long tubular structures closed at the apex, each from 8 to 12 μ in diameter, and reaching a length of 1-1·5 mm. in a damp atmosphere. The wall of the root-hair is composed of cellulose which allows the absorption of soil solutions to proceed freely by osmosis; the cell wall becomes more or less mucilaginous and particles of soil adhere to it.

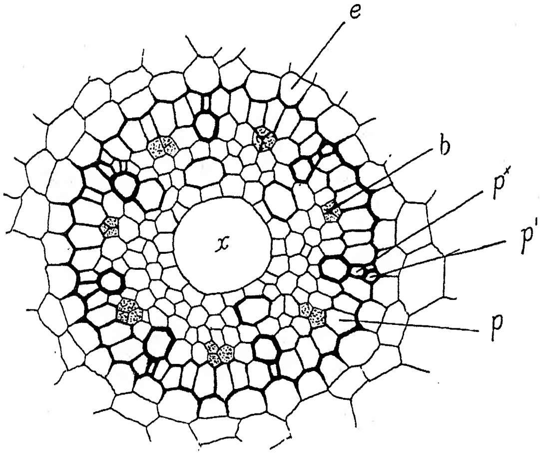


FIG. 27.—Vascular cylinder of a heptarch seminal root (× 210). p^x, Protoxylem; other letters as in the previous figure.

Lining the hair is a delicate peripheral layer of cytoplasm which increases somewhat in thickness near the tip. The nucleus of the cell from which the root-hair arises frequently migrates into the hair and travels along the lumen towards the apex, at the same time becoming elongated up to 40-50 μ (Fig. 28): ultimately it becomes disorganised when the root-hair shrivels and dies.

The zone of cortex which measures about 200 μ across consists usually of 6-8 layers of parenchymatous cells with small intercellular spaces, the individual cells being from 20 to 40 μ in diameter.

The endodermis is a single continuous layer of closely fitting cells; its outer walls are thin, but the inner walls in older roots are strongly cuticularised and exhibit lines of stratification; the radial walls are thickened also to some extent, especially where they join the inner surface of the cells (*e*, Fig. 29).

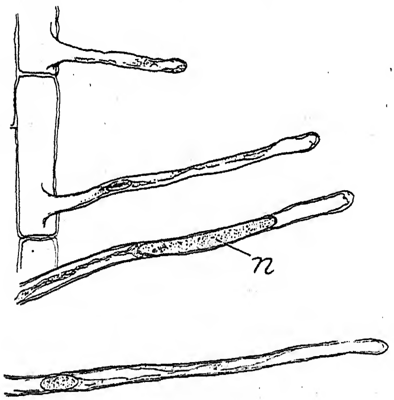


FIG. 28.—Root-hairs (×260). *n*, Nucleus.

The pericycle is a single layer. Its component cells, whose radial diameters are somewhat larger than their breadths, are of fairly uniform dimensions except at the points opposite the protoxylem, where they are very small. After a time their walls become more or less sclerotised and lignified.

The xylem strands are usually 7 or 8 in number in the seminal roots. One or two very narrow vessels, 5-10 μ in diameter, with closely arranged annular or spiral thickening, constitute the protoxylem of each bundle; the centripetal vessels formed later are pitted and wider, being 15-20 μ in diameter. In most primary roots and some secondary ones the centre of the vascular cylinder is occupied by a single large pitted vessel about 50 μ in diameter; in other roots there is no central vessel, but two or more large vessels are found distributed irregularly in the conjunctive tissue.

The phloem bundles are arranged alternately with the xylem strands; each generally consists of three cells (*b*, Figs. 26, 27).

The conjunctive parenchyma of the cylinder has moderately thick cell walls.

The piliferous layer soon ceases its absorptive function; the layer of cortical cells immediately within it then becomes transformed into the exodermis by suberisation of its walls, and acts for a time as a protective covering to the root.

Later, much of the cortical tissue shrivels, turns brown, and dies, but

the vascular cylinder retains its freshness, even in the case of the delicate seminal rootlets, during almost the whole life of the plant.

In roots from which the cortex has decayed, the endodermis, pericycle, and conjunctive parenchyma of the stele becomes very strongly sclerotic, but the cells of the bast and the xylem vessels preserve their normal character (Fig. 29).

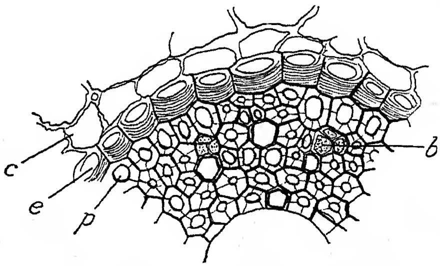


FIG. 29.—Transverse section of a portion of the vascular cylinder of an old seminal root examined in May (× 260). *c*, Cortex; *e*, endodermis; *p*, pericycle; *b*, phloem.

The anatomy of the stronger adventitious roots which spring from the nodes of the stems at or just above the surface of the soil differs in certain points from that of the seminal or thinner adventitious roots. The exodermis is often more persistent, and immediately within it there is frequently developed a zone of sclerotised cortical cells two or three cells thick (Fig. 30), which, for a time, protects

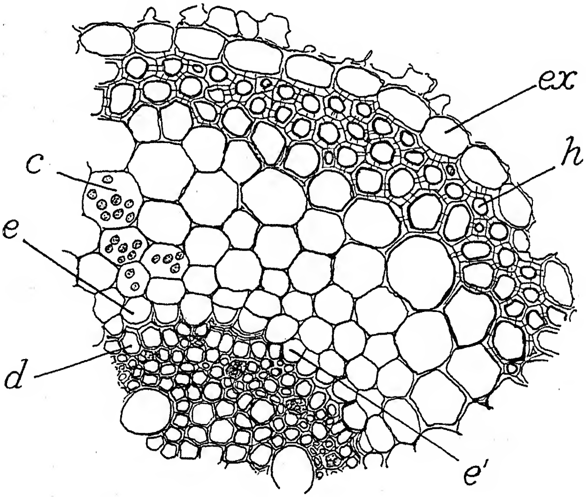


FIG. 30.—Transverse section of a portion of an adventitious root from the node immediately above the soil surface (× 150). *ex*, Exodermis; *h*, thick-walled cortical cells; *c*, thin-walled cortical cells containing chloroplasts; *e*, endodermal cell with thick inner wall; *e′*, thin-walled endodermal cell; *d*, lignified pericycle.

the turgid cortex within from collapsing. In the cells of the thin-walled cortical parenchyma of the stout adventitious roots arising from nodes just above the soil surface, numerous chloroplasts are found, especially in the inner layers, the central cylinder then appearing to be surrounded by a zone of green tissue.

For a time the endodermis of these roots is composed of thin-walled cells not very clearly differentiated from the adjacent cortex and pericycle cells ; later, the inner walls become extensively thickened except at points

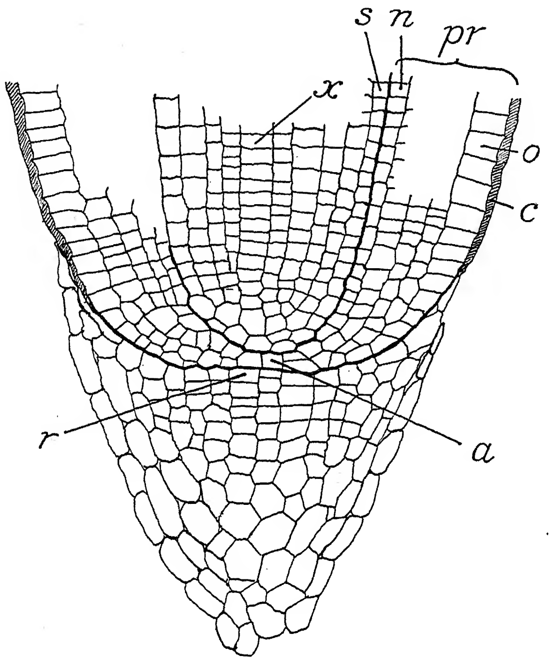


FIG. 31.—Median longitudinal section of the root-tip of a seminal root (×210). *a*, Initial cells of cortex and piliferous layer; *r*, meristem of root-cap; *pr*, periblem; *o*, outer layer of periblem with mucilaginous cell walls (*c*); *n*, endodermal layer; *s*, pericycle layer; *x*, central column of cells which develop into vessels.

opposite the xylem, where the walls remain thin, allowing the movement of water from the vascular cylinder into the cortex for a longer period than is the case in the more slender roots.

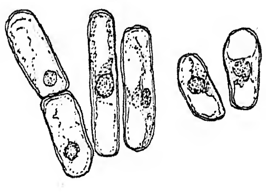


FIG. 32.—Recently exfoliated cells of root-cap (×210).

The pericycle at first consists of thin-walled cells which become thickened later.

At the growing-point of the roots of wheat are found the usual three layers of meristem which give rise to the vascular cylinder, the cortex, and the root-cap respectively.

The plerome or meristem of the vascular cylinder at the apex consists of a number of cells somewhat irregularly arranged ; its boundary, however, can be distinguished without much difficulty from the external periblem. The latter, from which the cortical tissues are developed, originates from one or two initial cells (Fig. 31).

The piliferous layer, when traced to the root apex, is seen to be the outermost layer of the periblem. Near the tip its cells have thick mucilaginous walls (Fig. 31).

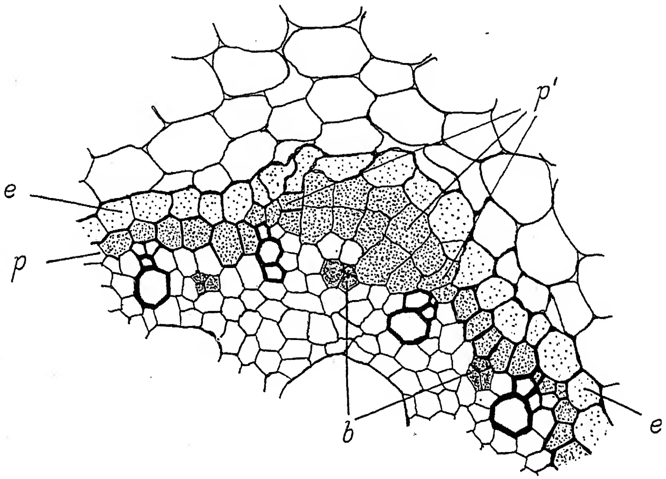


FIG. 33.—Transverse section showing the origin of a lateral root (p') from the pericycle p ($\times 385$). e, Endodermis; b, phloem.

Adjacent to the initial cells of the periblem is the meristem of the root-cap. As growth proceeds, the outer cells of the root-cap separate from each other along the middle lamella and are rubbed off by friction with the soil, through which the roots extend, the loss being made good by division of the meristem within. The exfoliated cells, at the time of their separation, are more or less turgid, and contain well-defined nuclei and vacuolated cytoplasm (Fig. 32).

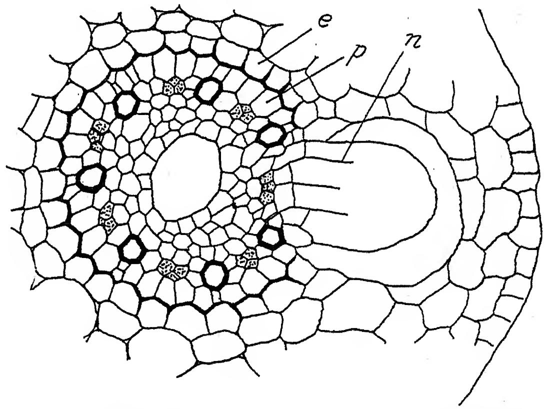


FIG. 34.—Transverse section of a root showing a lateral root (n), developing opposite the phloem ($\times 210$).

Lateral rootlets are derived from the cells of the pericycle opposite the phloem of the vascular cylinder, and not from points opposite the xylem as in the roots of many plants (Figs. 33, 34).

CHAPTER V

THE LEAVES

General Morphology

The wheat plant possesses several forms of leaves, viz.: (1) the *scutellum*, (2) the *coleoptile*, (3) the ordinary green *foliage leaves*, (4) the *prophylls* of the lateral axes, and (5) the *glumes* of the inflorescence. The scutellum has been considered already and the glumes will be dealt with later.

The coleoptile or plumule sheath which encloses the first shoot is a hollow cylindrical structure with a bluntish apex slightly curved to one side. I regard it as the primary prophyll or a leaf-sheath the blade of which is absent. Near its tip, on the side away from the scutellum, is a small slit through which the foliage leaves emerge (Figs. 9, 35).

In some forms of wheat the coleoptile is pale green or colourless, in others it is pink. The extent of its development varies with the depth at which wheat-grains are deposited in the ground. In crops drilled about an inch deep in the ordinary way in the field it comes to the surface or a few millimetres above it. In the case of grains sown 1·2 cm. (about half an inch) below the surface, the coleoptile grows to a length of 1·5 cm.: in those sown 2·5-5 cm. (1 to 2 inches) it usually measures about 3·5 cm., while in grains covered with 10 cm. (about 4 inches) of soil it reaches a length of about 6 cm.

It has few chloroplasts in its tissues and possesses little photosynthetic power: it functions chiefly as a protective cover to the young foliage leaves during their upward growth through the soil.

The foliage leaves of wheat, like those of grasses generally, are arranged on the culms alternately, in two opposite vertical rows, each leaf having a divergence of 180° from the next above and below it. This relationship is seen in the position of the coleoptile and first foliage leaf of the embryo.

In the case of lateral shoots, the first leaf is a binerved prophyll, somewhat resembling in form the coleoptile already described. It is semi-cylindrical, with an opening at the apex, through which the green foliage leaves emerge later. The upper part is green with deflexed hairs along

the margins of the two nerves : the lower part is colourless. The prophyll grows usually to a length of an inch or more and is inserted on the lateral shoot in such a position that its flattened side is turned towards the axis from which the shoot arises. The first foliage leaf, however, which succeeds this prophyll has a divergence from the latter of 90° only, to the right or left,

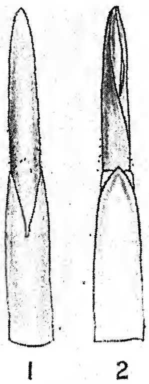


FIG. 35.—Tip of the coleoptile with first foliage leaf emerging. 1, Front; 2, back view.

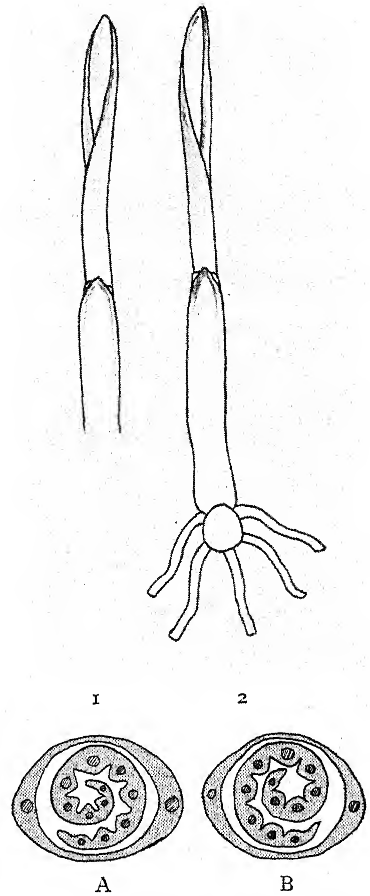


FIG. 36.—Young plants. 1, "Right-handed"; 2, "left-handed"; A and B, transverse sections of the shoots 1 and 2.

so that it and subsequent leaves which follow the ordinary rule of 180° divergence from each other are arranged in a plane at right angles to the foliage leaves of the preceding axis (Figs. 37, 38).

This is the normal arrangement of the leaves upon stems and lateral shoots in practically all grasses as first indicated by Godron.

In the bud the leaves are convolute, the blades being rolled up from one margin to the other. The rolling alternates from leaf to leaf, one in which the right margin is folded over the left being followed normally by another in which the left margin covers the right. The first foliage leaf of the embryo above the coleoptile is not, however, always rolled from the same side ; in some plants the right margin is folded over the left, in others the opposite arrangement occurs (Fig. 36). There are therefore two forms of plants which may be termed respectively " right- " and " left-handed,"

" right-handed " plants being those in which the right margin of the first green leaf-blade as seen from the front is folded over the left, " left-handed " being applied to those in which the left margin covers the right.

In Figs. 37 and 38 the order and mode of rolling of the leaves of the primary axis of the plant and the first two or three lateral branches is indicated. In the majority of right-handed plants the first green leaf of all the lateral shoots of the main stem is inserted on the left side of the secondary axis which bears it, the axis being viewed from the endosperm side of the scutellum: in those which are left-handed the first green leaf arises on the right side of its branch. In a small percentage of cases an alternate arrangement of the first leaves on the lateral shoots occurs (Figs. 37 and 38): other abnormalities are met with both in the succession and in the folding of the leaves.

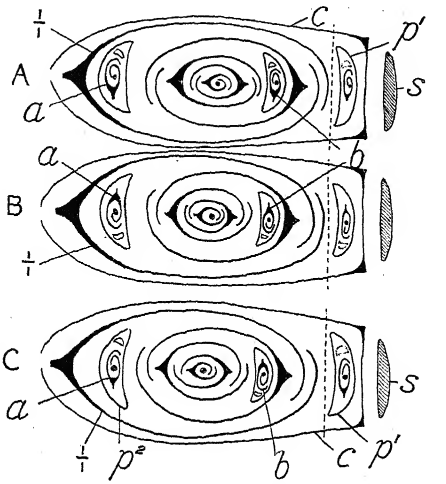


FIG. 37.—Diagrams of three types of leaf arrangement, A, B, and C, in young primary shoots. *s*, Scutellum; *c*, coleoptile; $\frac{1}{1}$, first foliage leaf; p^1, p^2, prophylls of first and second lateral shoots; *a*, first foliage leaf of shoot in axil of leaf $\frac{1}{1}$; *b*, first foliage leaf of shoot in axil of second leaf $\frac{2}{1}$.

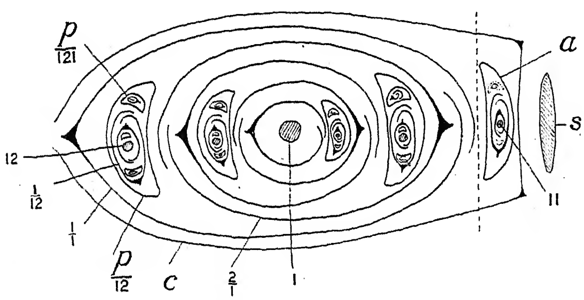


FIG. 38.—Diagram of the axes and leaf arrangements in young plant. *s*, Scutellum; *c*, coleoptile; 1, primary axis; 11, first, 12, second lateral axis of 1; $\frac{1}{1}$, first, $\frac{2}{1}$ second foliage leaf of primary axis; $\frac{p}{12}$, prophyll of axis 12; $\frac{1}{12}$, first leaf of axis 12; $\frac{p}{121}$, prophyll of first lateral axis of axis 12.

Out of 500 seedlings of a pure line of *T. vulgare* (Squarehead type), I found 276 with the left margin folded over the right, and 224 " right-over-left ": in a pure line of *T. turgidum* (Blue Cone) 256 were " left-over-right " and 244 " right-over-left ": in both these cases there is a preponderance of " left-over-right " plants.

The foliage leaves are of the ordinary linear gramineous type, possessing sheath, blade, and ligule, with a pair of auricles at the base of each blade.

The leaf-sheath, which is split in the upper parts but entire near the base, encircles the culm or straw, protecting the latter from damage by frost, drought, and insect attacks ; it possesses considerable strength and serves as a support for the young growing internode within it, and especially for the basal intercalary growth-zone, which remains soft and weak after the rest of the internode has become rigid.

The leaf-blade develops much more rapidly than the sheath, and in young plants reaches a length of two or three inches, while the sheath is not more than a few millimetres long. The sheath grows very little before the blade has attained its maximum size, but grows rapidly when the stem internodes begin to lengthen.

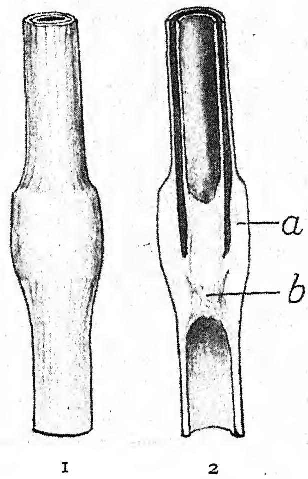


FIG. 39.—1, Node ; 2, longitudinal section through the node (× 2). *b*, Diaphragm ; *a*, thickened leaf-base.

The greater portion of the sheath is somewhat thicker and more transparent than the blade, with thin transparent margins. For a distance of 3-5 mm. above the point of insertion on the stem it is considerably thickened ; this short swollen part is about 1 mm. thick, and is often erroneously assumed to belong to the node of the culm (Fig. 39).

In many varieties the surface of the sheath is glabrous, while in others it is clothed more or less uniformly with short deflexed hairs. Sometimes there is a line of cilia near the outer margin of the sheath, and in *T. aegilopoides*, *T. monococcum*, and *T. dicoccoides* the hairs on the swollen base are longer than those of other wheats, forming a conspicuous white muff-like band round it.

The leaf-blade is linear- and parallel-veined ; its midrib projects on the back and is continued some way along the sheath as a raised line. It is twisted into the form of a loose right-handed screw, the twist being increased by holding the tip of a young leaf and turning clockwise (Fig. 40). The direction of the screw is normally the same for all leaf-blades, although exceptions are occasionally found, and it is independent of the alternately reversed convolute rolling of the young leaves previously noticed.

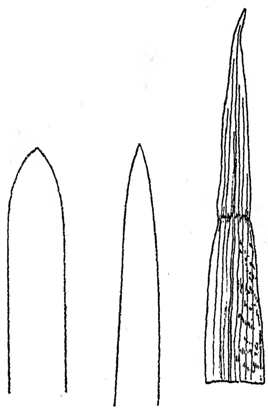
The halves right and left of the midrib are of different widths, the wider and narrower portions alternating regularly in successive leaves.

The narrow side is also slightly longer than the wider half, an arrangement which places the attached auricles one below the other alternately.

The blade of the first green leaf of the wheat plant differs from all the succeeding ones in having a somewhat stiffened bluntish apex, in outline like an arch, a form which enables the top to push its way through the soil without damage (Figs. 35, 41). The characteristic and easily recognised shape of this leaf greatly assists in the determination of the number of separate plants in a crowded row of seedlings in the field.

The blades of all other foliage leaves are drawn out into long acuminate points which are slightly hooded. About 1½ to 2 inches from the top of a full-grown leaf is a peculiar constriction, the margins curving inwards at that point giving to the blade the appearance of being formed of two pieces (3, Fig. 41).

FIG. 40.—Young leaf-blade showing spiral twist (nat. size).



1 2 3

FIG. 41.—1, Apex of the first foliage leaf; 2, apex of second foliage leaf; 3, apex of older leaf-blade (nat. size).

On the upper surface is a series of longitudinal and slightly raised ribs, which on the young leaves of *T. dicoccoides*, *T. dicoccum*, and *T. turgidum* are covered with soft velvety hairs of nearly uniform length; in *T. monococcum* the hairs are short and scabrid, in *T. durum* the blades are glabrous, while in *T. vulgare*, *T. Spelta*, *T. aegilopoides* there are long hairs on the summits and shorter ones on the flanks of the ridges (Figs. 111, 164).[1] The long hairs of *T. aegilopoides* tend to disappear when the plants are brought under cultivation.

The lower surface of the leaf is not ribbed and is usually smoother than the upper surface.

At the base of the upper surface of the leaf-blade is the ligule, a thin membranous structure which closely invests the stem and prevents the access of rain, dust, aphides, and other insects between the leaf-sheath and the stem (*l*, Fig. 42). It is colourless, and its free edge is irregularly cut and fringed with minute hairs. The ligules of the upper leaves are from 3 to 4 mm. long, those of the lower leaves much shorter.

The auricles are curved claw-like appendages attached to the base of each leaf-blade, where they loosely clasp the sheath and stem from opposite

[1] The ridges and hairs on the surface of the leaf are readily seen on bending the blade outwards and examining with a pocket lens (× 8) the folded part as a silhouette against the sky or other light background.

sides. They are usually pale green or pinkish in colour, and their margins and tips are often fringed with a few long unicellular hairs (*a*, Fig. 42).

As indicated previously, they are not exactly opposite to each other; the lower one is always connected with the narrower and longer half of the leaf-blade, and as this half alternates from right to left in successive blades, the lower auricle follows the same succession, encircling the sheath and straw from the right and left alternately.

On young leaves and on those of the lower nodes of the straw which die off soon, the auricles are small, but on the upper leaves they are more strongly developed. The size also varies with the race and variety of wheat, those of *T. Spelta* and *T. dicoccum* being the largest; the free claw in some cases attains a length of 4 or 5 mm.

The number of leaves on a well-developed straw of the various races of wheat depends partly on the variety and the vigour of the individual plant. In most varieties of *T. vulgare* as grown in the field, about 70 per cent of the straws possess 6 leaves, 8 or 10 per cent have 7, and about 20 per cent only 5 leaves. In varieties of *T. turgidum* 20 per cent have 7 or 8 leaves, about 60 per cent 6 leaves, the rest only 5 or less.

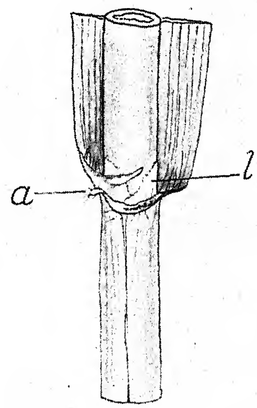


FIG. 42.—*a*, Auricle of leaf; *l*, ligule (× 2).

The total length of each leaf, *i.e.* the combined length of its sheath and blade, increases from below upwards to the fifth, which is the longest on the straw; the sixth or uppermost is invariably shorter than the one immediately below it. The average lengths of the leaves (sheath and blade) of the primary straw of the different races of wheats are given below.

AVERAGE LENGTH OF SUCCESSIVE LEAVES IN INCHES

	1st. (Lowest.)	2nd.	3rd.	4th.	5th.	6th.	Total Length of Five Uppermost Leaves (Inches).
T. monococcum	..	12·5	13·5	14·0	11·5	11·3	62·8
T. vulgare	..	12·5	15·4	16·6	17·7	17·1	79·3
T. Polonicum	..	16·5	17·0	16·8	17·0	18·0	85·3
T. amyleum	14·5	15·5	17·5	16·8	18·0	18·0	85·8
T. compactum	..	15·3	17·0	18·0	19·2	17·7	87·2
T. Spelta	13·3	15·4	18·0	18·5	19·0	18·5	89·4
T. durum	14·4	16·9	19·4	20·1	20·5	19·7	96·6
T. turgidum	16·2	18·4	20·5	21·8	22·4	21·1	104·2

The width of the blades of different leaves increases more or less regularly from the lowest to the uppermost leaf of the culm: the average breadth across the middle of the blades of the successive leaves of fifty well-developed straws of *T. vulgare* (Squarehead form) was:

Leaf . . .	1st	2nd	3rd	4th	5th	6th
Width . . .	6.3	9·2	10·3	11·6	14·3	17·1 mm.

The longest leaves are possessed by *T. turgidum* and *T. durum*.

In the following table is given the average separate lengths of sheath and blade respectively, deduced from measurements of successive leaves of the chief straw of fifteen plants of the different wheats mentioned.

LENGTHS OF SHEATH AND BLADE (inches)

	1st. (Lowest.)		2nd.		3rd.		4th.		5th.		6th.	
	Sh.	Bl.	Sh.	Bl.	Sh.	Bl.	Sh.	Bl.	Sh.	Bl.	Sh.	Bl.
T. monococcum.	..	..	4·0	8·5	4·5	9·0	5·0	9·0	5·0	6·5	6·3	5·0
T. vulgare .	..	..	4·9	7·8	5·8	9·6	6·5	10·1	7·4	10·3	9·3	7·8
T. Polonicum .	..	..	7·0	9·5	7·0	10·0	7·3	9·5	8·0	9·0	10·5	7·5
T. amyleum .	5·0	9·5	5·5	10·0	6·3	11·2	6·6	10·2	7·7	10·3	9·5	8·5
T. compactum .	..	..	5·7	9·6	6·0	11·0	6·6	11·4	7·5	11·7	9·0	8·7
T. Spelta . .	5·3	8·0	5·8	9·6	7·0	11·0	7·5	10·8	8·2	11·0	9·6	8·8
T. durum . .	6·0	8·4	6·6	10·3	8·0	11·4	9·0	11·1	9·0	11·5	10·7	9·0
T. turgidum .	6·4	9·8	7·3	11·1	8·3	12·0	9·1	12·7	10·2	12·2	11·8	9·3

DIFFERENCE BETWEEN SHEATH AND BLADE

	Leaves.				
	2nd.	3rd.	4th.	5th.	7th.
T. monococcum . . .	4·5	4·5	4·0	1·5	−1·3
T. vulgare	2·9	3·8	3·6	2·9	−1·5
T. Polonicum	2·5	3·0	2·2	1·0	−3·0
T. amyleum	4·5	4·9	3·6	2·5	−1·0
T. compactum	3·9	5·0	4·8	4·2	−0·3
T. Spelta	3·8	4·0	3·3	2·8	−0·8
T. durum	3·7	3·3	2·1	2·5	−0·3
T. turgidum	3·8	3·9	3·6	2·0	−2·5

On comparing the figures it is seen that the length of the sheath of successive leaves increases upwards, the uppermost being the longest. The blades also exhibit a successive increase from leaf to leaf up to the fifth, but that of the sixth or uppermost is always shorter than the blade of the leaf below it.

In all leaves except the terminal one the average length of the blade is from 2½ to 4 inches longer than the sheath associated with it; but the

blade of the uppermost leaf is usually 1-2½ inches shorter than its sheath.

The length of any particular sheath is approximately equal to the arithmetical mean of the sheath lengths of the leaves immediately above and below it, a relationship similar to that which exists between the lengths of separate internodes of fully developed straws.

The figures for the sheaths of *T. turgidum*, *T. Spelta*, and *T. compactum* are :

	T. turgidum.		*T. Spelta.*		*T. compactum.*	
	Length.		Length.		Length.	
	Found.	Calculated.	Found.	Calculated.	Found.	Calculated.
	inches.	inches.	inches.	inches.	inches.	inches.
Second sheath .	7·3	7·35	5·8	6·15	..	..
Third sheath .	8·3	8·2	7·0	6·75	6·0	6·15
Fourth sheath .	9·1	9·25	7·5	7·6	6·6	6·75
Fifth sheath . .	10·2	10·45	8·2	8·5	7·5	7·8

In the other races of wheat mentioned, the agreement between the calculated length and that actually observed is not quite so close, a discrepancy which is possibly due to the averages given in the table containing measurements of leaves which had not all reached their maximum development or whose normal growth had been disturbed.

Anatomy of the Leaves

1. *The Coleoptile and Prophylls*

The tissues of the coleoptile are of a simple character. Outside is an epidermis of long cells of rectangular outline with thin straight walls : there are no hairs present. One or two single rows of stomata run from the base to near the tip, on each side of, and parallel to the vascular strands within the leaf, the number of stomata increasing towards the apex, where they are crowded together in an irregular manner.

The few chloroplasts present are found in most abundance in the first layer of cells beneath the epidermis and in the parenchyma surrounding the vascular bundles ; they remain colourless except when the coleoptile is exposed to light.

In the majority of wheats two vascular bundles are found on opposite sides of the coleoptile. These are simple and straight for the greater part of their length : at the summit they bend towards each other and

meet in a backward pointing V-shaped curve, one or two very fine strands of tracheids anastomosing with them just below their point of union.

In *T. dicoccoides* and Indian and Abyssinian forms of *T. dicoccum* three to six vascular bundles are present in the coleoptile (Fig. 16), a fact which supports the view that the latter is homologous with the leaf-sheath or prophyll rather than with the ligule. The bundles consist of a few small scattered xylem elements of nearly uniform diameter and a mass of phloem protected on the outside by a single or double layer of thick-walled cells (Fig. 44).

The epidermis of the prophylls is composed of elongated rectangular cells with thin straight walls. Along the two margins of the flat side of the prophyll are reflexed unicellular hairs, and near the apex two lines of stomata run on opposite sides of the nerves. The mesophyll consists chiefly of delicate parenchyma; the cells of the apical portion round the nerves contain chloroplasts, the rest of the tissue being colourless. The convex part of the prophyll is transversed by 10-12 very thin, straight, vascular strands, two stronger bundles running from the base to near the apex in the angles where the convex and flat side meet (Fig. 45). Here and there, especially near the tip, are fine anastomosing lines of tracheids. A well-defined strand of stereome strengthens each of the two angles, and, in addition, two or three cells of rudimentary sclerenchyma are found beneath the outer epidermis of the convex side associated with the fine vascular strands.

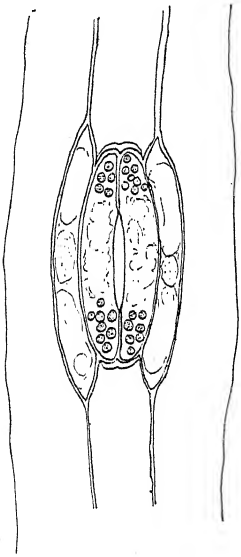


FIG. 43.—Stoma of the coleoptile (cf. Fig. 49) (× 380).

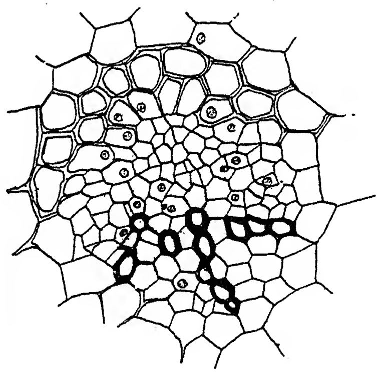


FIG. 44.—Transverse section of a vascular bundle of the coleoptile (× 280).

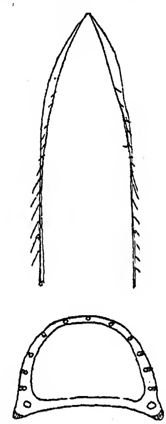


FIG. 45.—Outline and transverse section of a prophyll.

2. *The Foliage Leaves*

The structure of the green foliage leaves of the wheat plant is more complicated. Covering the surface is (1) a somewhat elaborate epidermis with characteristic stomata and trichomes of various forms; within is (2) the green assimilating parenchyma, (3) the conducting vascular bundles, and (4) longitudinal strands of fibrous stereome or supporting tissue.

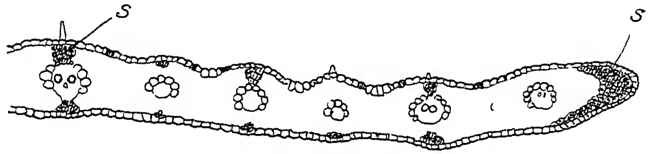


FIG. 46.—Transverse section of the leaf-blade. *s*, Stereome.

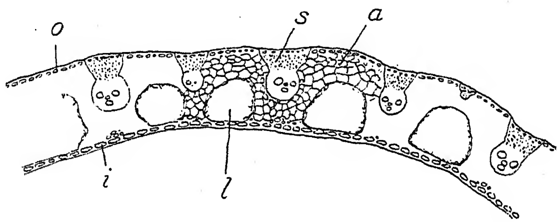


FIG. 47.—Transverse section of the leaf-sheath (× 25). *o*, Outer; *i*, inner epidermis; *l*, lacuna; *s*, stereome; *a*, mesophyll.

(i.) THE BLADE AND SHEATH. (*a*) *The Epidermis*.—The epidermis of the blade of the foliage leaves is composed of a number of diverse elements arranged in parallel rows along the long axis. Some of the individual rows consist entirely of elongated cells placed end to end, each cell appearing in longitudinal section as a narrow rectangle 150-300 μ long and 15-20 μ wide. In other rows short square cells 15-20 μ across are intercalated here and there between the long cells: characteristic lines of long cells alternating with stomata are also present, and, except in *T. durum*, trichomes or hairs of various lengths are found scattered along the rows at more or less regular intervals, the whole arrangement as seen in surface view being illustrated in Fig. 48. On the upper surface of the blade is a series of longitudinal ridges or ribs, the lower surface being almost flat. The epidermal cells covering the ridges differ somewhat in form and arrangement from those over the furrows and along the edge of the leaf.

Running along the summit of each ridge is a single row of elongated thick-walled and pitted cells alternating with hairs.

On the flanks of the ridge, right and left of this central line, are three to five rows of long cells often interspersed with short ones and hairs:

parallel to these, at the base of the ridge, are single or double lines of stomata.

In the furrow between two ridges is a band of three to seven rows of elongated cells, whose walls are thinner and not so distinctly parallel to each other as those of the long cells in other parts of the blade: these are termed "bulliform cells" by Duval-Jouve and "motor cells" by Pée-Laby. They are somewhat shorter than the ordinary long cells of the epidermis, measuring 100-250 μ in length and 17-20 μ in width: in transverse section they are seen to be deeper and of different form from the neighbouring cells, being spread out in the form of a fan, each cell being narrow at the outer part, and broader or smaller at the base within the leaf, where it is in contact with the assimilating parenchyma (*a*, Fig. 56).

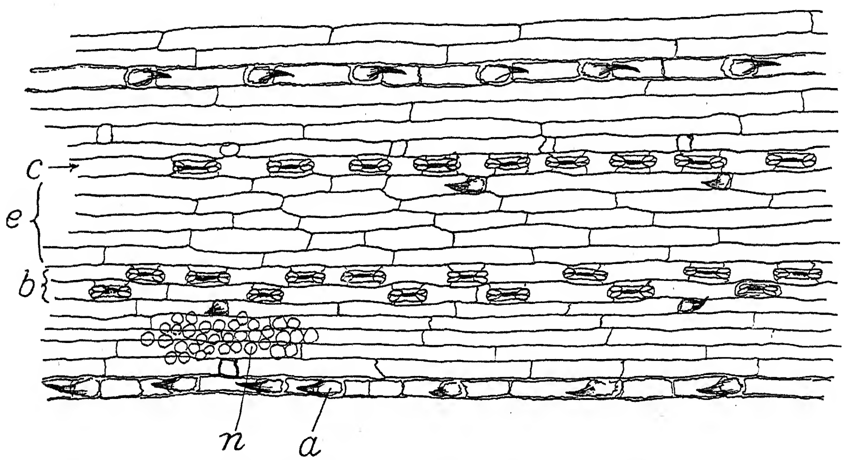


FIG. 48.—Upper surface of the leaf-blade. *a*, Hair; *b*, *c*, rows of stomata; *e*, rows of motor cells; *n*, optical section of mesophyll cells (× 105).

When transpiration is excessive these cells lose water and the edges of the lamina curve inwards, tending to check any further loss through the stomata, which are abundant on the upper surface. On reabsorption of water the blade becomes flat again.

The rest of the epidermis is of fairly uniform thickness, 25-30 μ deep, each cell about as long as broad, with a convex cutinised outer wall 4-5 μ thick, the inner and lateral walls being much thinner.

Several rows of epidermal cells bordering the edges of the leaf-blade have specially thick sinuous walls.

The trichomes or hairs on the leaf-blade are always unicellular, and vary much in length and stoutness; some of them on the edges of older leaves are little more than blunt prominences, others are short and stout, 20-30 μ long, with fine curved points rendering the surface scabrid; on soft velvety leaves of *T. dicoccum* and *T. turgidum*, the hairs often attain

a length of 300-400 μ, while on *T. aegilopoides* the sparsely distributed long hairs on the surface of the leaf-blade measure 1 mm. or more.

When present the trichomes are distributed in somewhat regular order, at short intervals along the rows of epidermal cells on the margins and surfaces of the blade. There are usually more on the upper than the lower epidermis, and in *T. vulgare* the longest hairs are found in the row of thick-walled cells which runs along the summit of each ridge; shorter ones are frequent on the flanks of the ribs, but few are seen among the motor cells.

Each stoma of the leaf-blade consists of four cells, the two guard cells being narrow, with specially thickened walls round the stomatal pore and thin-walled widely dilated ends: the pore when closed appears as a narrow slit 30-40 μ long (Fig. 49).

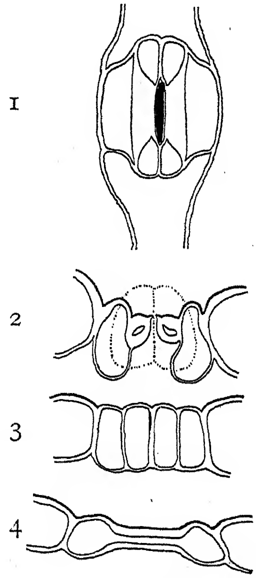


FIG. 49.—1, Stoma, surface view; 2, median transverse section; 3, transverse section across one end; 4, longitudinal section of a guard cell (× 380).

The stomata are only very slightly sunk below the general level of their neighbouring cells and run in single or double longitudinal lines, each stoma alternating more or less regularly with an elongated epidermal cell. On the upper surface the rows on one side are contiguous with the motor cells, and on the other side lie next to several rows of long cells without stomata.

In transverse section the pores of the stomata are seen to be in communication with large intercellular cavities in the mesophyll. The epidermis of the lower surface of the leaf resembles that of the upper surface in form and arrangement of its elements, but there are no definitely marked ridges upon it, and motor cells are absent: the cell walls are sinuous and much thickened, especially in the lower half of the blade. The hairs are also fewer in number, and the stomata more often in single lines than on the upper surface.

The ratio of the number of stomata on the upper and lower epidermis respectively is usually about 10 : 7, the number found on the upper surface in the few cases examined being about 7000 per square centimetre.

The outer epidermis of the full-grown leaf-sheath is composed of rows of elongated cells similar in form to those of the blade, but the walls are more sinuous and stoutly thickened (Figs. 50, 52).

The stomata are arranged in lines, as on the lamina, and a few hairs are usually present. Over the thick nodal base of the sheath the epidermis consists of much shorter cells, in the rows of which, at more or less

regular intervals, are pairs of cells, the upper one oval, the lower one broader and curved (Fig. 50); trichomes when present arise from the oval cells.

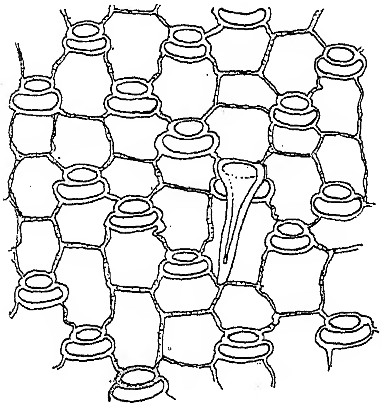


Fig. 50.—Outer epidermis of the base of a young leaf-sheath (× 210).

The cells of the inner epidermis of the sheath are thin-walled. Intercalated in the rows lying between the points opposite the vascular strands, especially near the upper part of the sheath, are short hairs, the tips of which are directed forwards (Fig. 51). A few stomata of a simpler pattern than those of the blade are found in this region of the inner epidermis; these communicate with larger lysigenous lacunae in the mesophyll.

(*b*) *The Parenchyma of the Leaf.*—The parenchyma of the blade of the foliage leaf consists chiefly of thin-walled assimilating tissue, containing lenticular chloroplasts 4·5-6 μ in diameter. Just within both the upper and lower epidermis the cells are

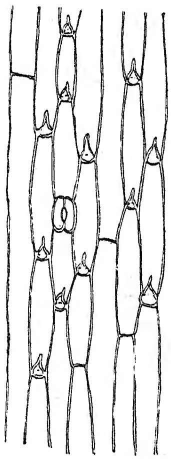


Fig. 51.—Inner epidermis of the leaf-sheath (× 50).

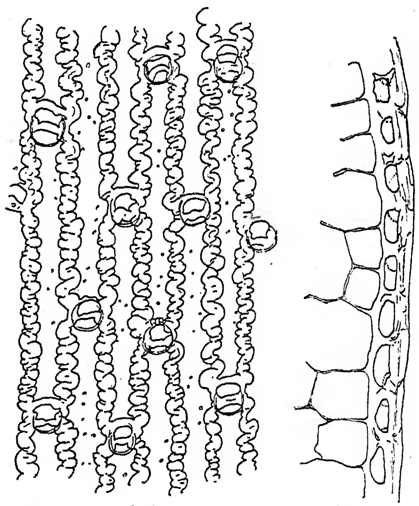


Fig. 52.—A, Outer epidermis of the leaf-sheath; B, transverse section of the same (× 210).

somewhat elongated and arranged in a more or less regular manner, with their long axes at right angles to the surfaces of the lamina, both layers suggesting a resemblance to the palisade parenchyma of a leaf of a

dicotyledon. In optical surface view the cells appear as circles from 20 to 32 μ in diameter (*n*, Fig. 48).

The cells of the chlorophyll-containing tissue in the central part of the leaf are much more irregular in shape and are loosely packed, with larger intercellular spaces between them.

The assimilating tissue of the leaf-sheath is arranged in parallel strips between the vascular strands, chloroplasts being present to a depth of three or four cells from the outer epidermis only; the rest of the parenchyma on the inside of the bundles and near the inner epidermis is colourless.

Extending longitudinally throughout the greater part of a full-grown sheath are large lysigenous cavities between the vascular bundles (*l*, Fig. 47).

The ground tissue of the thick nodal part of the sheath is composed of parenchymatous cells somewhat flattened when young and more or less hexagonal in transverse section, with unlignified walls 4 μ thick (Fig. 58).

Chloroplasts are present especially in the subepidermal layers. In each cell on the outside of the stereome, and between the vascular bundles, there is a single crystal or cluster of crystals of calcium oxalate (Fig. 58). The crystals appear to be waste products connected with the processes involved in the thickening of the neighbouring cell walls. Starch grains, 4 μ in diameter, are also found in the two or three cell layers of the ground tissue on the inner side of the xylem of the bundle.

(*c*) *The Vascular Bundles*.—Running through the ground tissue of the blade, somewhat nearer to the lower than the upper surface, are the vascular bundles, three types of which may be recognised, viz.: (1) stout bundles running longitudinally from the base to the apex of the blade, (2) more slender bundles parallel to and lying between the strong ones, and (3) very fine transverse veins which cross more or less obliquely from one longitudinal strand to another.

The number present in a leaf depends upon the size of the latter and its position on the plant, the upper leaf often possessing more than three times as many bundles as the lowest leaf on the straw. The first foliage leaf of a seedling plant of *T. vulgare* usually has 11-13 bundles, 3-5 of which may be traced to near the apex. In a full-grown leaf on a well-developed straw there are generally 9-13 stout bundles, and between each pair of these there may be 1-5 slender intermediate strands, the most frequent number being 2 or 3.

Below are given the number found in the broadest part of the several leaves on a full-grown straw of *T. vulgare*.

When the bundles are traced from the base towards the apex, some of them, instead of remaining as single strands throughout their course,

Leaf.	Stout Bundles.			Fine Intermediate Bundles.	Total.
	Left Half.	Midrib.	Right Half.		
5th or uppermost .	6	1	6	66	79
4th	6	1	6	42	55
3rd	6	1	6	31	44
2nd	4	1	4	28	37
1st leaf near base of straw . . .	4	1	4	18	27

are seen to divide where the leaf becomes wider, the two halves gradually separating into distinct bundles.

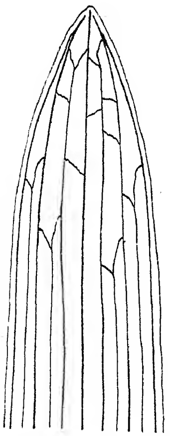


FIG. 53.—Course of the vascular bundles near the apex of a leaf-blade (× 5).

On the other hand, in the upper part of the lamina, some of the finer bundles disappear not by blindly ending in the mesophyll, but by turning to one side and uniting with another; others somewhat stouter divide in two, the separate parts then curve rapidly to the right and left respectively and become joined to neighbouring parallel bundles as indicated in Fig. 53.

On account of these divisions and fusions of bundles, the number found varies with the part of the leaf chosen for examination, being greatest in the middle and least near the tip.

The vascular bundles from the leaf-blade pass uninterruptedly into the sheath and downwards into the node, where they enter the diaphragm between two adjoining internodes (pp. 95-97).

All the bundles are collateral, with the xylem towards the upper surface of the blade, the phloem below.

In the xylem of the stout strands there are one or two vessels about 20 μ in diameter, with annular or spiral thickening, and to the right and left of these are two vessels, usually of wider bore, with narrow elliptical pits.

In the slender intermediate bundles few or no vessels are visible, although xylem and phloem are both present.

The very fine anastomosing bundles, which cross from one parallel bundle to another, consist of short tracheids about 6 μ in diameter, with parallel thin-walled parenchymatous cells about 4 μ across accompanying them (Fig. 54).

Each bundle is surrounded by an inner and an outer sheath (Fig. 55); the former (the "mestome" sheath of Schwendener) completely encloses the vascular strand, and is composed of elongated thick-walled cells

usually with square ends and a few simple pits; the outer or "parenchyma sheath" is more conspicuous, especially round the smaller bundles, and consists of thin-walled cells, often almost circular in transverse section,

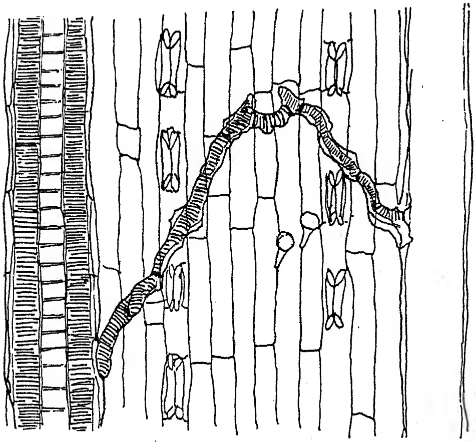


FIG. 54.—Fine strand of tracheids crossing from one large bundle to another (optical view of portion of leaf cleared with chloral hydrate (× 135).

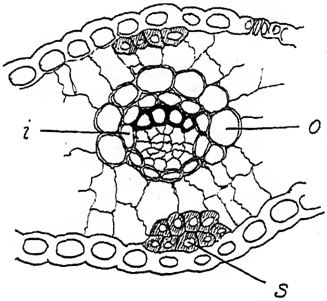


FIG. 55.—Transverse section of the leaf through a small vascular bundle (× 210). *s*, Stereome; *i*, inner; *o*, outer bundle sheath.

measuring 20-30 μ across and 100-150 μ in length, their long axes parallel to the long axes of the leaf. It only partially encircles the bundle, being

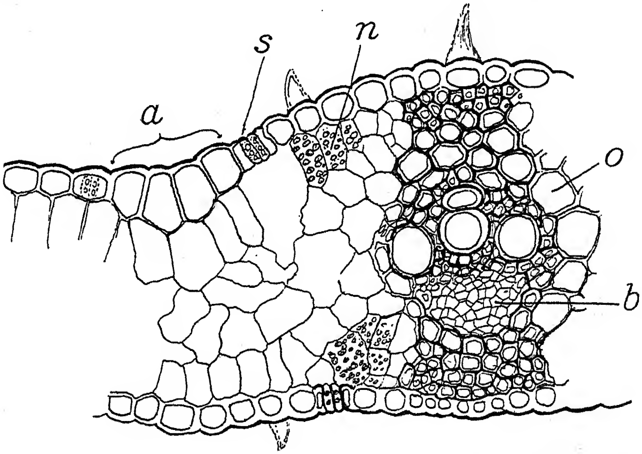


FIG. 56.—Transverse section of a leaf through a large vascular bundle (× 210). *a*, Motor cells; *s*, stoma; *n*, mesophyll cells; *b*, phloem of vascular bundle; *o*, outer sheath of bundle.

discontinuous on the phloem side, and in the larger bundles is united to the girder of stereome mentioned below. Unlike the ordinary parenchyma of the blade, the outer sheath contains few or no chloroplasts except when

young ; in the nodal part of the leaf-sheath, however, the outer bundle-sheath retains its chloroplasts for some time, accumulating later a large number of fine round starch grains, each about 4 μ in diameter.

(*d*) *Stereome of the Leaf.*—Above and below the bundles, and arranged parallel with them along the leaf, are strands of stereome or supporting tissue consisting of sclerenchymatous fibres, some of the walls of which are so much thickened that the lamina of the cells are almost obliterated. In the case of a thin intermediate bundle, small isolated stereome strands, consisting in some instances of three or four cells only, are present immediately within the upper and lower epidermis above and below the bundle, the space between the latter and its corresponding sclerenchymatous strands being occupied by ordinary thin-walled ground tissue. The stereome above and below a stout bundle is, however, more extensive, usually filling up the space and forming a strong girder between the epidermis and the sclerenchymatous bundle-sheath with which it becomes united.

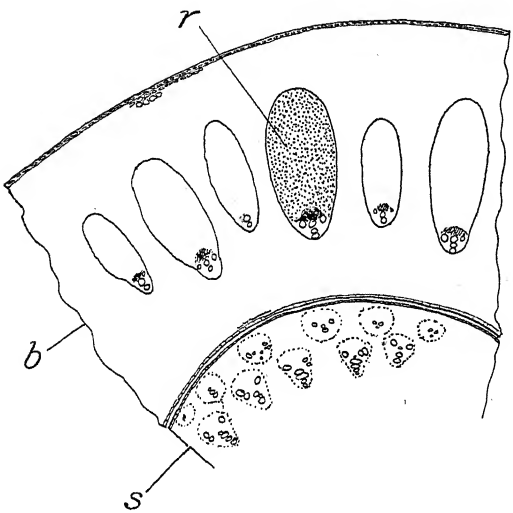


FIG. 57, 1.—Transverse section of the leaf-base just above a node (×25). *s*, Stem; *b*, leaf-base; *r*, stereome of bundle.

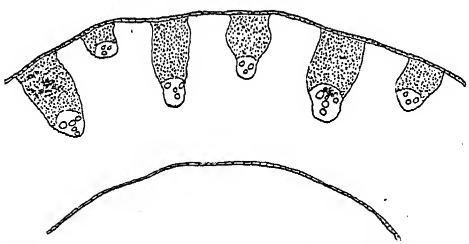


FIG. 57, 2.—Transverse section half an inch above 1 (×25).

In the leaf-sheath the vascular bundles are girdered to the outer epidermis by strands of stereome continuous with those of the under side of the blade. On the inside of the sheath, which corresponds with the upper surface of the blade, only a few cells of stereome are seen beneath the epidermis opposite to the larger bundles but not connected with them as a girder ; opposite to the smaller bundles none is developed. Traced downwards, the stereome increases in amount, reaching a maximum in the thick nodal portion of the sheath, where it forms a strong strand of semi-elliptical section on the outside of each vascular bundle and free from the epidermis

(Fig. 57): the fibres in the middle part of the thick leaf-base remain unlignified for some time after those in the upper and lower sections of it have changed.

In addition to the stereome associated with the vascular bundles there is a stout band of mechanical tissue 80-100 μ wide, along both margins of the leaf-blade just within the epidermis, which greatly assists in keeping flat the edges of the leaf; it is absent from the edges of the leaf-sheath.

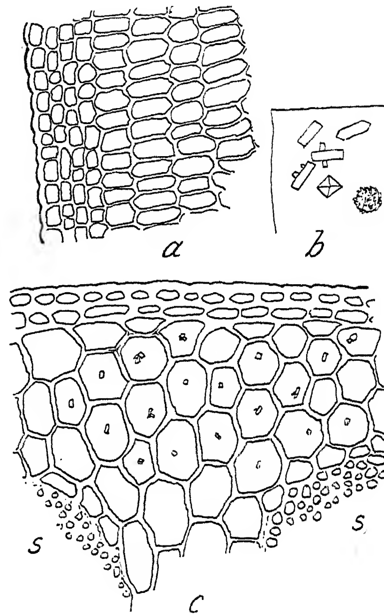


FIG. 58.—*c*, Transverse section of a portion of the leaf-base ($\times$ 105); *s*, stereome of bundles (cf. Fig. 57); *a*, longitudinal section of parenchyma cells in *c*; *b*, calcium oxalate crystals from cells in *c*.

(ii.) THE LIGULE.—The ligule, often 2·5 to 3 mm. long, is an emergence of thin-walled parenchyma arising at the point of union of blade and sheath, its inner epidermis being directly continuous with that of the leaf-sheath; it possesses no vascular tissue.

At the base it is three or four cells thick. Along the thinner upper free edge many of its cells are elongated, forming an irregular fringe of unicellular hairs, each 60-80 μ long, and 8-10 μ broad. Both surfaces are without stomata or hairs, and the walls of the epidermis, especially at the margins and back of the ligule, frequently show faint transverse scalariform puckering. The cells are 5-10 times as long as broad, most of them colourless, but some contain small chloroplasts, and others a pinkish cell-sap.

(iii.) THE AURICLES.—The auricles consist of parenchyma; some of their epidermal cells are unicellular hairs from ·5 to 1 mm. long.

CHAPTER VI

THE STEMS: "TILLERING," "SHOOTING," AND "LODGING"

General Morphology

The culms or straws are erect, elastic, cylindrical, and in some wheats, especially *T. dicoccoides*, *T. turgidum*, and *T. Polonicum*, more or less furrowed, with smooth or scabrid surfaces. The upper parts in a young state are green, and carry on the process of assimilation extensively, the straw and investing leaf-sheaths being able to supply sufficient food to mature and ripen grain even when the leaf-blades are removed at the time of flowering of the ear.

When ripe the colour in most wheats is a pale yellow; in some, however, the upper internode is a characteristic purple tint about the time of harvest.

In normally grown plants of Bread wheat the majority of the culms possess six nodes, although straws with seven and also with five are not infrequent.

At the nodes, which should not be confused with the swollen bases of the leaf-sheaths, the stem is much contracted in diameter and always solid, the vascular bundles being there crowded together and interlaced to form a strong diaphragm between two internodes (Fig. 39).

In most varieties of Bread wheats the internodes are hollow, but in many kinds of Rivet and Macaroni wheats the central part of the straw is completely filled with a soft pith. In the hollow straws the cavity begins to form when the young internode is about half an inch long, the separation of the cells appearing first in the upper part of the internode just below the diaphragm.

The whole length of the lower, and much of the upper internodes are invested by the leaf-sheaths, which function as protective and supporting structures to these sections of the straw, especially when the latter are immature.

The length attained by a straw is influenced by a number of independent factors, some races, *e.g.* Rivet wheats (*T. turgidum*) and Macaroni

wheats (*T. durum*), usually have tall stems, while Small Spelt (*T. monococcum*) and Bread wheats (*T. vulgare*) are generally shorter, but tall and more or less dwarf varieties occur among almost all the races of wheat. The particular length attained is not only dependent upon the race or variety of wheat, but also upon various external conditions.

The application of nitrogenous manures increases the length of the straw: phosphates and potash fertilisers tend to reduce it.

Plants grown at wide intervals have taller stems than those which are more crowded together, and the amount of moisture in the soil greatly modifies the development of the straw.

The lengths of the several internodes increase from the base to apex of the straw, the uppermost internode being always the longest in plants which have received no check in their growth.

From measurements upon Rye and other cereals, Nowacki concluded that the length of each internode upon a normally grown and fully developed straw is the arithmetic mean of the lengths of the internodes immediately above and below it. It is possible to find individual stems whose measurements closely approximate to this formula, especially among short-strawed varieties of wheat, but Nowacki's law is not generally true, neither in respect of the straws of an ordinary field crop nor of those of plants grown a foot or more apart from each other.

Below are given the average lengths of the internodes of long and short straws of a variety of *T. vulgare* and one of *T. turgidum*.

AVERAGE LENGTHS OF INTERNODES (cm.)

Internodes.	1.	2.	3.	4.	5.	6.	Total Length of Straw.
RED SQUAREHEAD (*T. vulgare*)							
Long straws—	cm.	cm.	cm.	cm.	cm.	cm.	cm.
Found	3·6	8·9	12·3	19·2	30·3	49·8	124·1
Calculated	..	7·9	14·0	21·3	34·5	..	..
Short straws—							
Found	2·0	4·6	8·6	14·4	24·0	36·0	89·6
Calculated	..	5·3	9·5	16·3	25·2	..	..
BLUE CONE (*T. turgidum*)							
Long straws—							
Found	3·4	6·4	10·4	15·6	29·4	60·0	125·2
Calculated	..	6·9	11·0	19·9	37·8	..	..
Short straws—							
Found	2·1	3·6	6·4	9·9	19·2	39·0	80·2
Calculated	..	4·2	6·7	12·8	24·4	..	..

The diameter of the straw is influenced by the same numerous factors as those which affect the length; especially stout stems are generally found on plants which are grown at wider intervals than one foot apart.

The average diameter of the separate internodes increases from below up to the fifth; the sixth or upper internode is more slender than the rest. Each individual internode is thickest in the middle, from which point it tapers more or less evenly to both ends.

The average thickness of the wall of the straw decreases from the base to the apex; similarly, the thickness of the wall of each internode is greatest at the base and diminishes gradually from below upwards.

The following are measurements of the diameters of the internodes, the thickness of the wall, and thickness of the zone of hypoderm of hollow straws of *T. vulgare* (Squarehead) taken from an ordinary field crop.

Internode.	Average Diameter.	Diameter.		Thickness of Wall.	Average.	Thickness of Hypoderm.
	mm.		mm.	μ.		μ.
6th (upper)	3·03	top	2·40	412	440	115-150
		middle	3·85	380		115
		base	2·85	528		150
5th . .	4·18	top	3·90	445	507	115-150
		middle	5·05	500		85-115
		base	3·60	577		85-150
4th . .	4·15	top	3·95	460	570	85-115
		middle	4·65	510		85-100
		base	3·85	740		85-150
3rd . .	3·88	top	3·62	528	604	85-115
		middle	4·20	545		85-100
		base	3·82	740		85-150
2nd . .	3·56	top	3·50	577	642	85
		middle	3·65	610		85-115
		base	3·55	740		
1st . .	3·43		3·43	740	740	170

"Tillering"

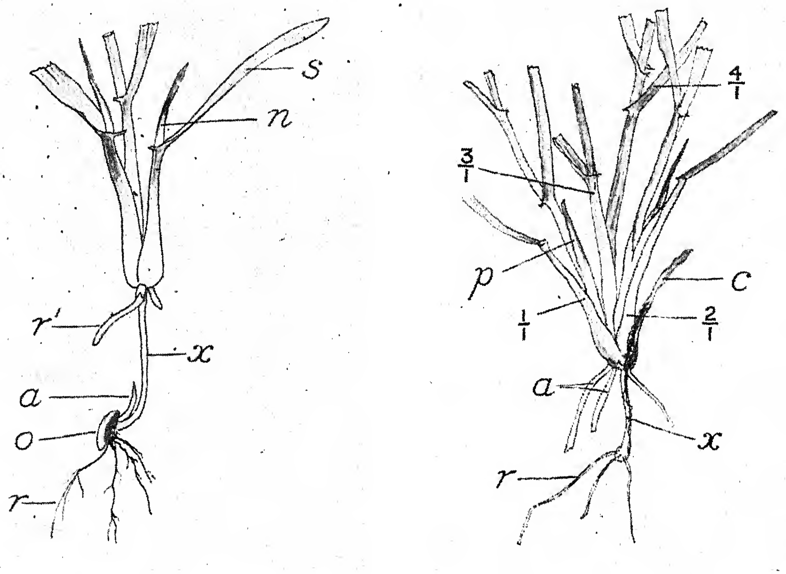
The primary stem of the wheat embryo within the grain is extremely short, and consists of hypocotyl, or portion below the point of insertion of the scutellum, and the epicotyl, or axis of the plumule.

When growth commences in grains sown in the ordinary way in the field, the hypocotyl remains short, but the lower part of the epicotyl

lengthens into a thin erect rhizome which pushes the terminal bud upwards through the soil.

This rhizomatous portion of the stem is from ·6 mm. to 1 mm. in diameter, much thinner than the aerial straws of the plant, and is usually the second internode of the epicotyl. When grains are sown at a depth of four inches or more, the second and third and sometimes other internodes above these often lengthen to form part of the rhizome (Fig. 61): at depths of three inches or less, the rhizome usually consists of the second internode only.

In plants grown from grains sown three inches deep, the first, second,



1 2

FIG. 59.—Young plants with shoots at the "tillering" node. *o*, Scutellum; *r*, seminal roots; *r′* and *a* (in 2), adventitious roots; *x*, rhizome; *a* (in 1), shoot in axil of coleoptile; *c*, shrivelled coleoptile; *n*, prophyll of first shoot; *s*, leaf-blade of 1st leaf; $\frac{1}{1}$, $\frac{2}{1}$, $\frac{3}{1}$, and $\frac{4}{1}$, 1st, 2nd, 3rd, and 4th leaves of primary axis; *p*, prophyll of first shoot.

and third axillary buds of the main stem remain dormant or give rise to weak shoots, the fourth lateral bud being the first to produce a strong shoot.

The third axillary bud is generally the first to grow strongly when grains are deposited two inches in the soil, the second developing most rapidly when the grain is sown one and a half inches down.

The bud in the axil of the first foliage leaf grows out immediately when the grain is placed nearer the surface of the soil.

The length of the rhizome varies with the depth at which the grains are deposited. When the latter are placed on the surface, or less than an

inch below, the rhizome is scarcely visible, being rarely more than two or three millimetres in length; at greater depths it lengthens proportionately in such a manner that the plumule of the young plant produced from a grain sown at any depth between one and three inches is lifted up to within an inch or less of the surface (Fig. 60).

When the primary bud has reached this point, the rhizomatous internode ceases to lengthen, and the succeeding internodes of the plumule remain short.

During autumn and spring, however, the primary axis continues to

1 2 3 4 5 6

FIG. 60.—Wheat seedlings from grains sown at depths of 1-6 inches. Note extent of tillering, length of rhizome, and number and length of adventitious roots from the first (tillering) node. (About half natural size.)

grow very slowly, and, at the same time, in the axils of its leaves buds are formed which expand into short secondary stems; the latter also bear axillary buds which are capable of developing in a similar fashion into branches of the third order, and so on. Thus, from the primary bud of a single wheat grain, a large number of stems may be produced, which remain very short until April, at which date they usually begin to expand, the strongest of them ultimately growing out into straws each with its terminal ear.

The production of these numerous shoots with unexpanded internodes, which takes place near the surface of the soil, is known as the "stooling" or "tillering" of the plant; it is the normal process of branch formation in cereals and grasses generally.

The depth at which "tillering" or "stooling" begins, that is the

point at which the plumule is arrested in its upward growth through the soil, is regulated chiefly by the light-perception of the plant, and by the depth at which the grain is sown.

In shady places the tillering node is found nearer the surface than in sunny open ground, and a continuance of dull weather after late sowing tends to shallow tillering.

The following measurements obtained from plants derived from grains sown at carefully controlled depths illustrate the influence of depth of sowing on the length of the rhizome, and the depth of the tillering node below the surface.

Depth of Sowing.	Length of Rhizome.	Depth of Tillering Node.
inches.	inches.	inches.
·5	·1	·4
1	·5	·5
1·5	1·0	·5
2	1·6	·4
3	2·2	·8

The arrangement and order of development of the several branches may be followed by the dissection of young plants in different stages of growth.

In the resting embryo within the grain, the terminal primary bud is visible with its axis and two or three rudimentary leaves ; the first lateral bud is also seen in longitudinal sections in the axil of the coleoptile (Fig. 10).

Ten or fifteen days after germination commences, more lateral buds are formed, one in each axil of the alternate leaves on opposite sides of the primary axis (Fig. 62). Expansion of the latter soon commences ; its first internode, namely, that below the first lateral bud in the axil of the coleoptile, always remains very short ; the second, however, grows considerably, forming a more or less elongated rhizome as already described, the terminal bud with its lateral buds being pushed upwards in the soil to the tillering point.

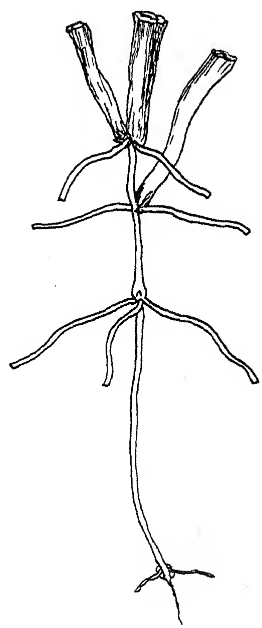


FIG. 61.—Rhizome of three internodes.

After the plumule has been carried upwards to this position, the buds in the axils of its two lowest foliage leaves develop rapidly, the plant

then showing three green shoots above ground, one on each side of the main stem, arranged in alternate order, *i.e.* with a divergence of $\frac{1}{2}$ or 180°. Two more shoots soon spring from the primary stem above the first pair, and about the same time each of the two first branches give rise to two alternate branches of the second order arranged in a plane at right angles to that of the first pair, the plant then consisting of nine shoots, the relative position of which can be easily recognised in upright growing spring forms of wheat: in the winter types, however, which for a time are decumbent, the shoots soon bend out of the planes in which they arise and appear arranged more or less in a semi-circle close to the ground: the arrangement of the first nine axes of the plant is indicated in Fig. 63. Additional branches may arise later, not only on the primary axis, but on stems of the second, third, and higher order, the plant ultimately consisting of a very large number of crowded leafy shoots, with short unexpanded internodes, the whole forming a dense tuft, the visible parts being, of course, the blades of the leaves with portions of their sheaths, the axes or stems from which they spring being short and hidden from view.

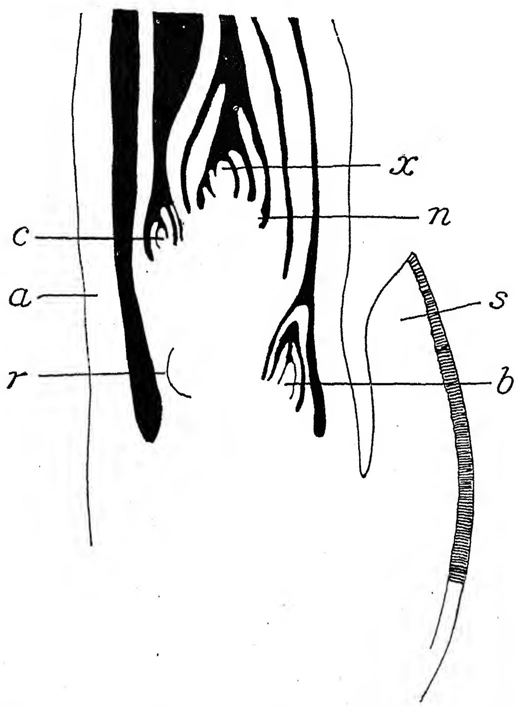


FIG. 62.—Longitudinal section through a young plant 14 days old (× 25). *s*, Scutellum; *a*, coleoptile; *b*, bud in the axil of the coleoptile; *c*, bud in the axil of the first foliage leaf; *n*, bud in the axil of the second foliage leaf; *x*, terminal bud; *r*, adventitious root.

Schoute's method of indicating the various axes or branches of the plant is convenient. The primary axis is denoted by the figure 1, its 1st, 2nd, 3rd . . . branches by the figures 11, 12, 13 . . . respectively.

Similarly, the figures 1, 2, 3 . . . may be joined to these to indicate the 1st, 2nd, 3rd . . . branches of these axes: *e.g.* 132 denotes the 2nd branch of the 3rd branch of the primary axis (Fig. 64).

The leaves on the several axes may be expressed in the form of a fraction, the denominator of which denotes the axis, the numerator referring to the number of the leaf on that axis: *e.g.* $\frac{2}{1}$ indicates the 2nd

leaf of the primary axis, $\frac{2}{12}$ the 2nd leaf on the 2nd branch of the first axis, and so on (Fig. 59).

Very distinct differences in the habit of growth are visible in autumn and early spring among young wheat plants of different varieties. Two extreme types are readily recognised, namely, (1) the *erect* type (Fig. 65), with shoots which spring up almost vertically, and (2) the *prostrate* type, whose leafy shoots lie on the surface of the soil; between these is (3) an *intermediate* type (A and B, Fig. 66), with shoots which grow up at a variable angle with the horizon. The three types may be indicated by the symbols |, /, —: these characters are constant and are easily distinguished except when the plants are abnormally crowded and "tillering" is checked.

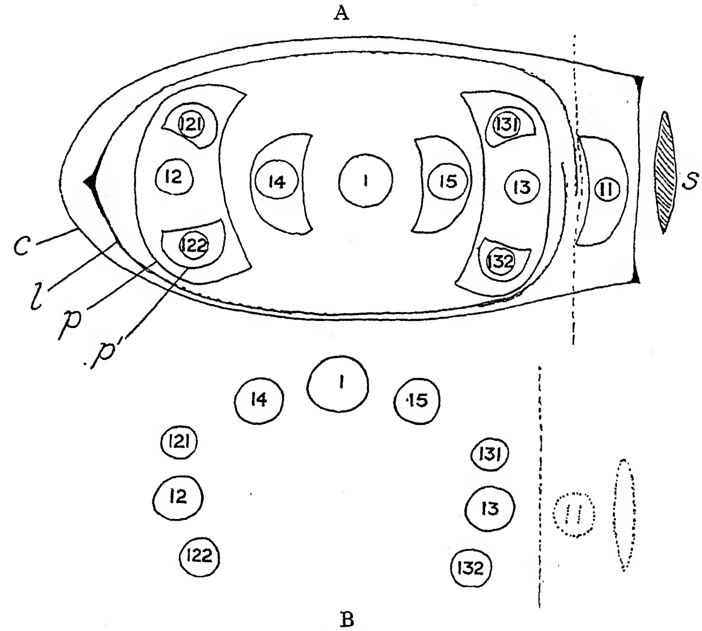


FIG. 63.—A, Diagram of the arrangement of the axes of a young plant; B, relative position of the axes later; *s*, scutellum; *c*, coleoptile; *l*, first foliage leaf; *p*, *p'*, prophylls.

In those of erect habit the young shoots form a somewhat compact tuft, and the culms of the mature plant converge at the base to a narrow point just below ground, resembling the ribs of a nearly closed umbrella (A, Fig. 67): they are very liable to lodge and are easily pulled out of the soil. The tendency to grow in this manner is sometimes seen in plants with only two leaf-blades developed, the first blade then making but a narrow angle with the second.

In plants of the prostrate habit the first leaf-blade becomes horizontal soon after the second blade appears. Later, the several shoots of the young plant curve away from each other and soon come to lie close to the surface

of the soil, the strongly curved parts at this stage being the short leaf-sheaths (A, Fig. 66). The extreme forms of this type are sometimes called by farmers "creeping wheats." The culms of the fully developed plant are bent at their bases, the whole being arranged in the form of a cup (B, Fig. 67). Wheats with this habit do not easily lodge and are so firmly rooted in the ground that they are difficult to pull up.

In wheat plants of an ordinary field crop the development of the shoots does not always proceed with the regularity described above. The first lateral bud,

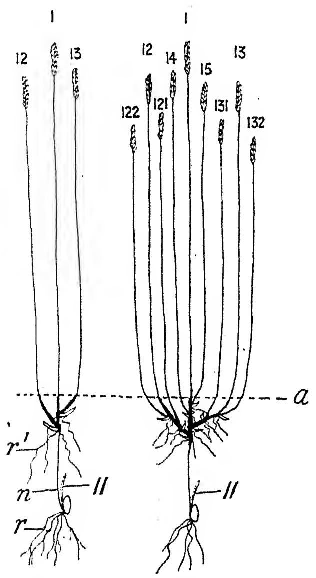
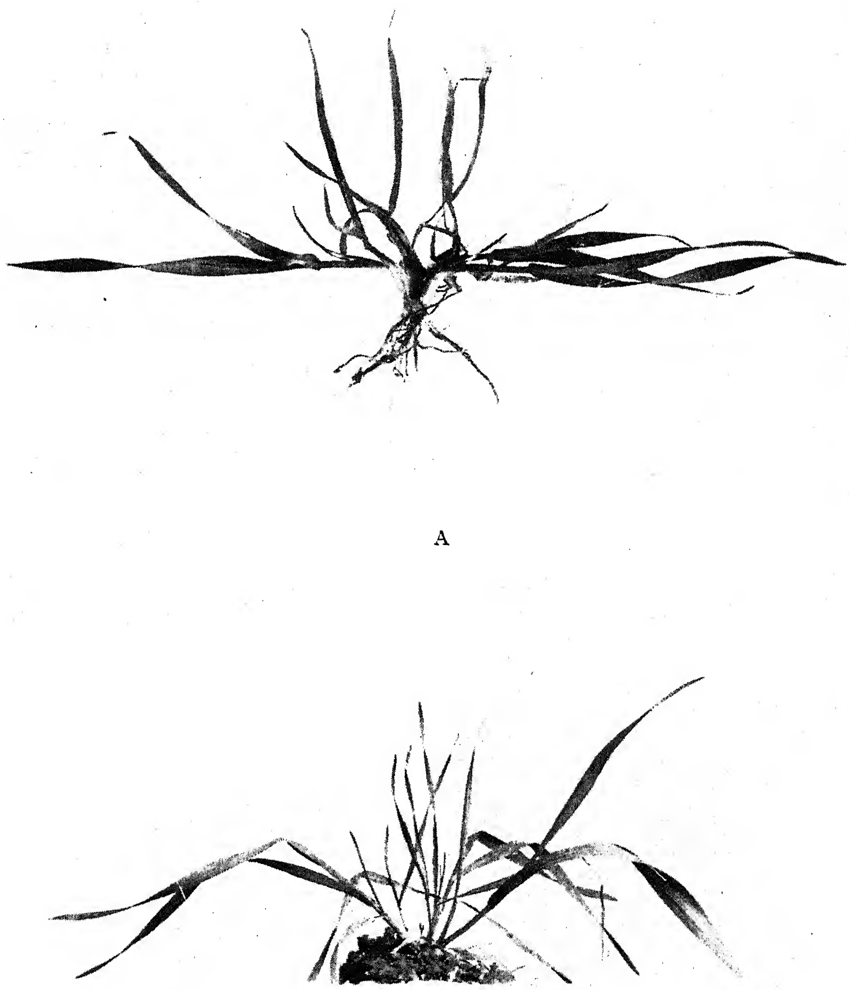


FIG. 64.—Diagrams of the arrangement of the culms of tillered plants.

FIG. 65.—Young plant with erect habit.

namely that in the axil of the coleoptile, generally remains dormant or dies off altogether; occasionally it develops and remains close to the hypoctyl: the internode above it, carrying the growing point and lateral buds upwards to the tillering region, the first lateral shoot in such an example appearing to arise from the base of the rhizome some distance below the rest of the shoots which spring later from the tillering nodes (*a* (1), Fig. 59). Many later buds fail to develop, and the branching and distribution of the shoots are therefore not so symmetrical as would be the case if the buds in the axils of every leaf grew out in the order of its

production. Moreover, crowding occurs, and the tillering process is often checked after the formation of a comparatively small number of shoots, and plants with two or three stems only are frequent.



A

B

FIG. 66.—Young plants. A, Prostrate habit; B, semi-erect.

A strongly tillered plant, however, grown in an isolated position from a single grain sown early in good soil, may possess a hundred shoots or more in spring, which may develop ears yielding several thousands of grains at harvest.

Although the buds and branches originating during the tillering period may, under favourable conditions, amount to a very large number, unless the plants have ample space for development and the soil is in a highly fertile condition, many of them are very weak and grow out into slender straws with small ears. In the majority of instances all the leafy "tillers" of a plant produce ear-bearing straws, but sometimes in an ordinary crop, where the individual plants "tiller" very little, some shoots die off even after they have reached a height of 3-6 inches. This is most frequently observed in dry seasons when the adventitious root-system associated with each shoot and essential to its nutrition has developed too late or has dried up before obtaining an adequate hold of the soil.

The extent to which tillering proceeds among the plants of a field crop of wheat is comparatively small, the majority of the grains rarely producing more than three or four fully developed straws.

Schoute found that out of 2895 plants examined in a Dutch crop

				Relative Frequency.
1845	plants produced only	1	straw	·637
601	,, ,,	2	straws	·208
318	,, ,,	3	,,	·110
78	,, ,,	4	,,	·027
27	,, ,,	5	,,	·0091
11	,, ,,	6	,,	·0037
5	,, ,,	7	,,	·0017
3	,, ,,	8	,,	·0010
4	,, ,,	9	,,	·0014
0	,, ,,	10	,,	..
1	,, ,,	11	,,	·0003
0	,, ,,	12	,,	..
1	,, ,,	13	,,	·0003
1	,, ,,	14	,,	·0003

63·7 per cent, or about two-thirds of the plants, gave one straw only, while 95·4 per cent yielded not more than three straws each.

The average number of straws per plant produced by 841 varieties, including representatives of *T. dicoccum*, *T. turgidum*, *T. durum*, and *T. vulgare*, grown in 1912–13 at Reading in rows 6 inches apart, the grains 6 inches asunder in the rows, was 5·4.

7	varieties	produced	1-2	straws	per plant.
34	,,	,,	2-3	,,	,,
137	,,	,,	3-4	,,	,,
163	,,	,,	4-5	,,	,,
183	,,	,,	5-6	,,	,,
133	,,	,,	6-7	,,	,,
74	,,	,,	7-8	,,	,,
50	,,	,,	8-9	,,	,,
22	,,	,,	9-10	,,	,,
38	,,	,,	over 10	,,	,,

While it is the rule that, under the conditions which prevail in fields receiving customary cultivation, each grain sown yields only a very few straws, there are nevertheless numerous records of very prolific plants arising from single grains sown in open rich ground and freed from competition with neighbouring plants. Patrick Shirreff mentions one with sixty-three ears containing 2473 grains, and another with eighty ears yielding 4522 grains; Haberlandt also refers to one bearing 130 ears which produced 6855 grains weighing 218 grams.

By dividing a tillered plant into separate parts, each with its adventitious roots, and transplanting the detached shoots into good ground, a very large number of ears and grains may be obtained in one season from a single grain.

C. Miller gives an account of the result of an experiment illustrating this method of increase. He states that he sowed a grain of wheat on June 2, 1765, and on August 8 lifted the plant and divided it into eighteen parts; the several shoots were then planted out singly and the division and transplanting repeated in September and October of the same year, sixty-seven plants being obtained. A third division and planting was carried out between the middle of March and the 12th of April in the succeeding year, producing 500 plants which at harvest yielded 21,109 ears and 47 lbs. 7 oz. of grain, the estimated number of grains deduced by calculation after counting and weighing a certain number being 576,840.

Incidentally, it may be noted here that as a process for the multiplication of new varieties of wheat, Miller's system of division and transplanting does not lead to such rapid increase as the practice of thin seeding; for, as Shirreff points out, the single grain which Miller used was sown early in June, and must have been obtained from the previous year's harvest, two years being required, therefore, to produce one crop. On the other hand, the plant mentioned by Shirreff, which from one grain produced 2473 in the first year, would yield 6,115,729 grains at the harvest of the second, or more than ten times as many as Miller's plant, if those obtained in the first season were each as productive in the second as the initial grain.

The extent of tillering which wheats exhibit is governed by internal physiological peculiarities of the plants, and also by various external causes.

Most varieties of *T. durum*, and many of *T. turgidum* tiller very little, while plants of *T. monococcum*, *T. dicoccum*, *T. Spelta*, and *T. compactum* usually give rise to a number of straws; even varieties of the same race, very similar to each other in form of ear and other morphological characters, often differ in branching and in stem production. Late forms usually tiller well, early forms tiller very little. The rapid-growing spring

varieties of *T. vulgare* with slender straws tiller more than the thicker strawed winter wheats.

Tillering capacity is not only dependent upon the inherent vital constitution of the species or variety concerned; it is also greatly influenced by internal qualities associated with difference in the size of the grain from which the plants are raised. In experiments carried out upon large and small grains which were sown in rows six inches apart, and three inches asunder in the row, I found that large grains selected from the ears of sixteen varieties of *T. vulgare* gave plants which produced an average of 8·1 stems per plant, while the small grains taken from the same ears gave plants yielding only 4·4 straws each. Even when the grains were grown at wider intervals, namely one foot apart each way, the plants from the large grains produced an average of 14 straws each, those from the smaller grains only 10·6 per plant.

Much of the increased luxuriance of the plants derived from large grains is doubtless to be attributed to the abundant food supply in the endosperm of such grains; some of it, however, may be the result of specific biological differences in the embryos of large as compared with those of small grains, although these differences are probably not of much magnitude in grains selected from the same ear. Nevertheless, the particular share in the variation of the tillering power which should be assigned to each of these two causes can only be determined by further experiment.

In addition to inherent qualities of the plants, other factors are concerned in the tillering process. Profuse tillering is an index of natural exuberant growth, and although the number, size, and vigour of the shoots produced rests to some extent upon the hereditary qualities of the species, variety, or form of wheat concerned, the branching and stem production attained by any particular kind is due in largest measure to the action of those external conditions which check or assist vegetative growth generally. The question is one chiefly concerned with nutrition, and the tillering of individual plants raised from grains taken from the same ear or spikelet depends to a greater or lesser degree upon those external conditions which favour or retard their nutritive functions.

The temperature of the soil and air, the amount and distribution of the rainfall, the intensity of the sunlight, and other climatic factors connoted by the term "season" have a controlling influence upon the tillering process. It is also greatly affected by the physical and chemical condition of the soil, the density of "seeding" or the amount of space allotted to each plant, and the date at which the grain is sown.

For the most vigorous growth of the wheat plant comparatively dry conditions are essential; excessive moisture of the soil or atmosphere greatly checks it and reduces tillering, especially when associated with low temperature as in winter.

The effect of the rainfall upon the number of straws produced by the plant is strikingly exhibited in the results of some experiments carried out during three years in order to determine the differences between autumn- and spring-sown crops.

Nineteen varieties were sown in October, and again in February, in the seasons 1910–11, 1911–12, and 1912–13, the plants being grown in rows six inches apart, the individual grain being deposited six inches asunder in the rows.

The average tillering power and the rainfall are given below :

	1910–11.	1911–12.	1912–13.
Rainfall—	inches.	inches.	inches.
Oct. to March . . .	14·2	19·6	12·7
Feb. to March . . .	2·9	5·0	3·2
Number of straws per plant—			
Autumn-sown . . .	5·0	2·7	5·4
Spring-sown . . .	6·5	2·5	6·0

The heavy rainfall in the winter of 1911–12 reduced the straws per plant to about half the number obtained in the previous and succeeding drier seasons, the effect being seen not only in the autumn- but in the spring-sown crops.

It was found also that grains sown in spring very frequently produced more straws and ears, though always of less average weight than those of the same variety sown some three or four months earlier in the previous autumn, the increase being most marked in the rapid-growing spring wheats of normally short vegetative period.

The table on the following page gives the number of straws and ears per plant produced by five typical winter and four spring wheats, sown in autumn (Oct.) and spring (Feb.) respectively, during three successive seasons.

Tillering only continues so long as the temperature is above the minimum for growth, and is most rapid at the optimum temperature : it almost ceases in mid-winter, but goes on to an almost equal extent in autumn and spring.

The date of sowing also influences tillering, since the degree of warmth and the amount of light available for the plant as well as the length of time for assimilation and vegetative growth are all correlated with it. Wheat sown early in autumn branches more than it does when sown later, although in most seasons the difference in the number of straws per plant is comparatively small among crops drilled at any time between late October and the end of January. It is in plants produced from grains

	1910–11.		1911–12.		1912–13.	
	Sown in		Sown in		Sown in	
	Autumn.	Spring.	Autumn.	Spring.	Autumn.	Spring.
			WINTER VARIETIES			
Red Squarehead . .	5·4	5·2	2·2	1·6	6·0	6·3
White Squarehead . .	4·4	5·3	2·0	1·6	3·4	5·3
Trump	6·4	6·4	2·4	1·1	4·8	5·7
Aleph	7·0	7·9	2·4	1·8	4·8	6·4
Hunter's White . .	4·0	5·5	2·6	2·8	4·6	5·7
Average . .	5·4	6·0	2·3	1·8	4·7	5·9
			SPRING VARIETIES			
Calcutta	4·4	7·2	1·7	2·8	..	..
March	6·6	8·0	2·0	1·8	6·1	10·0
Manitoba Fife. . .	5·6	7·7	2·6	2·6	5·8	8·0
Californian . . .	5·0	9·5	3·0	5·2	6·2	7·0
Average . .	5·4	8·1	2·3	3·1	6·0	8·3
Rainfall (Oct.-Mar.) .	inches. 14·2		inches. 19·6		inches. 12·7	

sown out of the ordinary English season, namely in April, May, or June, that the greatest effect of time of sowing is seen.

Winter wheats, or varieties with a long vegetative period, sown at any date after the end of April, and spring forms of short growing period, sown after the middle of June, go on tillering throughout the year in which they are sown into the next before sending up ear-bearing straws, the number of short unexpanded shoots or "tillers" produced diminishing more or less regularly as the date of sowing advances from the periods named.

In a series of experiments, in which grains of four varieties of wheat were sown at the University College Farm, Reading, every week throughout the year, the following results, as shown on page 77, were obtained.

Another factor which very materially modifies the stem and ear production in wheat is the space allotted to the individual plants of the crop.

Extensive tillering can only take place when each has ample room for its development; the roots especially must be free from competition with the roots of other plants, and allowed to permeate the soil in all directions without hindrance, if maximum tillering is to be attained.

Where the crop is crowded, owing to thick seeding of the grain, branching is much reduced; on the other hand, it is increased by thin

AVERAGE NUMBER OF STRAWS AND EARS PER PLANT

Sown in	Winter Varieties.		Spring Varieties.	
	Golden Drop.	Blue Cone.	Fife.	March.
1913. April	20	32	..	..
May	14	16·4	..	..
June	11	13·5	12·5	15·0
July	11	28·0	18·0	16·6
Aug.	..	..	11·0	11·3
Sept.	7·9	10·3	9·8	11·6
Oct.	..	7·3	8·3	9·7
Nov.	7·7	8·6	9·9	7·1
Dec.	6·6	12·6	9·1	9·7
1914. Jan.	5·5	8·0	6·6	8·8
Feb.	4·5	6·7	7·5	4·9
1912. March	4·3	7·4	7·0	7·7
April	..	..	3·8	5·3

seeding. In the case of good land, especially where it is well supplied with available plant food-materials, thin seeding often results in the production of the same number of straws per square yard as that obtained on a thickly sown field, the tillering process making good the loss in plants which thin seeding entails.

Where the land is in poor condition and the grain thinly sown, however, tillering does not make up for the loss of plants, and there is reduction in the number of straws per acre.

The following results were obtained in 1914 with a dense-eared variety of wheat sown in the previous autumn on poor soil, which had carried a crop of wheat during the three previous seasons, without the application of manures of any kind :

No. of Plants grown.	Area allotted to each Plant.	Average No. of Straws per Plant.
	square inches.	
600	6 (6″ × 1″)	1·6
350	18 (6″ × 3″)	1·5
200	36 (6″ × 6″)	1·8
200	72 (12″ × 6″)	2·9
100	144 (12″ × 12″)	4·0
60	576 (24″ × 24″)	7·0

On soil in such poor condition as this, where the rows were six inches apart, the number of straws produced by each plant was about the same, whether they stood 1, 3, or 6 inches asunder ; only when the rows were

12 or 24 inches apart was there any considerable increase in the tillering of the plants.

On soil in a high state of fertility the number of straws produced by each plant is usually twice or three times as large as these.

"Lodging"

On examining fields of cereals at harvest the crops are not infrequently found to be more or less "lodged" or laid, the straw being bent down to the ground, usually, though not always, because the lower internodes are too weak to support the upper leafy portion and the heavy ears.

This "lodging" or "laying" of the crop is of serious importance to the farmer, for it reduces the yield of grain, the ears of laid crops usually having many of their upper and lower spikelets barren or holding only poorly developed grains. Moreover, the straw and ears are discoloured; there is also much likelihood of damage to the grain by sprouting, especially in a damp season, and the labour and expense of harvesting is greatly increased by it.

Crops may go down at any time after the ear is out of the upper leaf-sheath, though it occurs most frequently, perhaps, in the latter half of June or a little later, when the plants are leafy and the grain is filling rapidly. So long as the straw is soft and green, and the cells of the nodes and thick basal portions of the leaf-sheath retain their vitality, the ears of a laid crop may to a greater or lesser extent regain their upright position through geotropic stimulus, the straws being bent upwards at each node until the uppermost internode is again vertical. Where "lodging" occurs early in the season the crop may therefore suffer comparatively little; if, however, it takes place late in the season when the nodal tissue is dying or dead, the straw and ears remain where they are laid.

Crops go down usually after heavy rain or violent winds, but the damage is only indirectly caused by these agents, the trouble being due to (1) specific weakness of the straw, associated in some cases with a natural drooping habit, and (2) to weakness of the roots, or to a root-system which has little grip on the soil. Wind and rain only reveal the weaknesses of the stems and roots of the crop but do not cause them. Where the straw is weak, the lower internodes are usually bent or broken when "lodged"; where the root only is at fault, the plant goes down as a whole, the straw being rigid and straight.

Some varieties of wheat, especially the dense-eared forms of *T. vulgare*, possess short stiff erect straws, which under normal conditions of growth do not easily "lodge." On the other hand, many Indian and Persian forms of *T. vulgare* have equally short but slender straws which, when the ears are ripe, assume a drooping position, and although the stems are strong and elastic enough to keep the ears off the ground in

dry warm seasons, they readily become laid after a heavy shower when grown at Reading.

Some tall lax-eared European forms of *T. vulgare* and varieties of *T. durum* and *T. turgidum* with slender straw exhibit this drooping habit in a slight degree, and are correspondingly liable to go down under conditions of weather which would not damage the stiffer erect straws of many European winter wheats.

The peculiar arrangement of the root-system and the strength of the individual roots, which are hereditary characters of different varieties of wheat, have a great influence upon the "lodging" of the crop.

In short-strawed winter wheats of the Squarehead type the bases of the straws just above the ground bend outwards in the form of a cup, and from their lower nodes arises a spreading system of adventitious roots (B, Fig. 67); the first inch or two of the roots below the surface is somewhat rigid and thickened considerably, and the cell walls of their tissues strongly lignified. By this spreading arrangement of strong roots the plants are firmly anchored to the soil and prevented from being laid except by the severest storms.

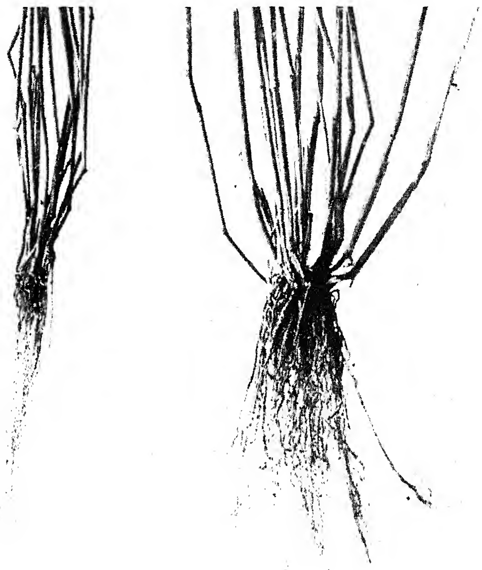

A B

FIG. 67.—A, Stems and roots of a "spring" wheat; B, a "winter" wheat.

In most spring forms, however, the straws grow up from the ground in a crowded more or less compact bundle, spreading very little, and the adventitious root-system consists of much thinner, less lignified roots closely contracted and descending almost vertically with very little grip on the surface soil (A, Fig. 67); plants with these root characters are very easily bent to the ground as a whole, although the straw may be as strong and rigid as that of the best winter varieties. "Lodging" of this kind, which may even occur among isolated well-grown plants, is due to weak root-hold, the straw being neither bent nor broken; it is frequently observed among rapid-growing oriental wheats when grown at Reading.

In addition to the hereditary characters of root and stem which influence the "lodging" of the crops, there are external factors which encourage "lodging," and the phenomenon, as ordinarily encountered in farm practice in this country, is most frequently associated with weakness of the straw due to the crowding of the plants. The weakness is chiefly an etiolation effect caused by insufficient light. In dense closely-grown crops the retarding action of light on growth is absent; lengthening of the lower internodes and of their cells occurs, and thickening and lignification of the mechanical tissues of the straw are greatly checked in dull light.

By comparing normal straws, which have had ample space for development and adequate exposure to light during growth, with those of closely grown crops, it is found that the lower internodes of the latter are somewhat longer, their diameter smaller, and their tissues somewhat softer than those of plants grown wider apart. The vascular bundles in straws of the same order, both in crowded and uncrowded plants, are similar in number, but their transverse sections and the cells of the hypodermal tissue are slightly smaller and the cell walls thinner in straws of crowded plants than in those of normally grown stems; both the hypoderm and mechanical tissue round the vascular bundles are reduced in weak stems, and their individual cells comparatively small and thin-walled; in the weakest crowded straws, which are sometimes little more than 1·5-2 mm. in diameter, the tissue outside the zone of vascular bundles up to the epidermal layer consists of cells with delicate walls only.

The strength of the straws of "unlodged" plants is chiefly due to the thick lignified walls of the hypoderm.

Crowding, which results in etiolation, to which the weakness of the straw is due, may be brought about in many ways; the sowing of too much seed per acre, drilling in rows too close together, early sowing, the application of large amounts of nitrogenous manures to the soil, a mild winter with abundant rain, and other conditions which encourage luxuriant growth may each produce it, and when several of these factors work together "lodging" is almost certain to follow sooner or later.

Large leafy plants when crowded together, whatever the cause of their luxuriance, are not only liable to "lodge" because the lower internodes are weakened by being shaded, but they go down more quickly than smaller plants because of the greater weight of their leaves and ears.

Experiments with various fertilisers on the wheat crop, carried on for several seasons at the College Farm, showed that the application of phosphatic and potassic fertilisers alone, even in very large doses, had little or no effect on "lodging"; on the other hand, plants grown with large amounts of nitrates of sodium, potassium or calcium, and sulphate of ammonia, invariably go down in crops of ordinary density because the straw is weakened by the etiolation which occurs.

Isolated plants grown with excess of nitrogenous manures frequently possess strong rigid straw capable of effectually resisting the strain of wind and rain ; they are, however, very liable to fall to the ground as a whole, their anchoring adventitious roots, which in normally grown plants bind the plant firmly to the soil and keep it upright, being soft and weak through the slight development, reduced thickening, and imperfect lignification of their mechanical tissues.

In common with stems of all grasses, wheat straw contains a considerable amount of silica, namely, from 2·3 to 4·6 per cent in its dry matter or 55 to 70 per cent in the ash ; it occurs chiefly in the cell walls of the epidermis, to which it imparts hardness. The strength and elasticity of straw was formerly attributed to the presence of this substance, and the application of soluble silicates to the soil was suggested by Way and others as a means of combating the tendency to "lodging." Pierre, however, discovered that the straw of laid wheat was as rich or richer in silica than that of standing crops, and his researches showed that the lower internodes of straws, on which the resistance to lodging chiefly depends, were always poorer in silica than the upper parts of the stem and leaves.

The investigations of Lawes and Gilbert also demonstrated that a high percentage of silica in the ash and dry matter of wheat straw is associated with brittleness and weakness of the latter, and occurs in seasons of bad harvests. Well-ripened straw of good seasons, possessing strength and elasticity, contains a high amount of lignified tissues and a correspondingly low proportion of silica.

The parasitic fungi, *Ophiobolus graminis* and *O. herpotrichus*, invade the lowest internode of the wheat plant, often so weakening or destroying its tissues that the straw falls to the ground.

Erysiphe graminis is also sometimes the cause of similar damage to the wheat crop. Where the attack is severe, large numbers of plants may go down ; the result, however, differs in appearance from true examples of "lodging," as, in cases of injury by fungi, the individual straws fall in all directions, whereas when laid by the wind or rain large portions of the crop are bent over in the same direction.

"Shooting" of the Stems and Escape of the Ear

Neither the primary axis nor any of the branches arising during the tillering period continue to produce lateral vegetative shoots indefinitely, for sooner or later inflorescences or ears originate at the apex of the branches, after which lateral bud formation ceases in those particular stems.

By an examination of longitudinal sections of very young shoots in

which ears can be detected, and also of full-grown culms or ear-bearing straws, it is seen that no buds are formed in the axils of five to seven leaves immediately below the ear itself.

In the ordinary course of events, where wheat is sown at any date between October and the early part of March, the young culms with their ears begin to expand in April. In all the shoots of the "tillered" plant in which the six leaf-blades of the several culms are visible, both the straw and ear can be readily recognised within the leaf-sheaths, although their combined length is then only about a quarter of an inch (Fig. 68). Growth advances from this stage onwards with increasing rapidity until the straw is 2 or 3 feet high, and the ear, almost full grown, is pushed out of the uppermost leaf-sheath into the open air, usually at the end of May or during June.

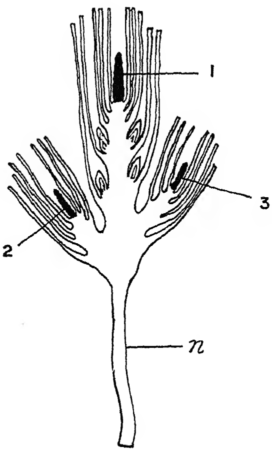


Fig. 68.—Longitudinal section of a young plant at the end of April. *n*, Rhizome; 1, 2, 3, ears.

The crop in which the elongation of the culms is taking place is said to be "shooting," the process consisting essentially in the expansion of the stems, which have originated in the previous "tillering" period.

While growth in length in the young stem is effected by the activity of an apical meristem, the straw also possesses intercalary growing-points, one at the base of each internode, which continue to lengthen the several sections of the culm after the upper part of each has ceased to grow; these delicate growing regions are protected by the surrounding leaf-sheaths.

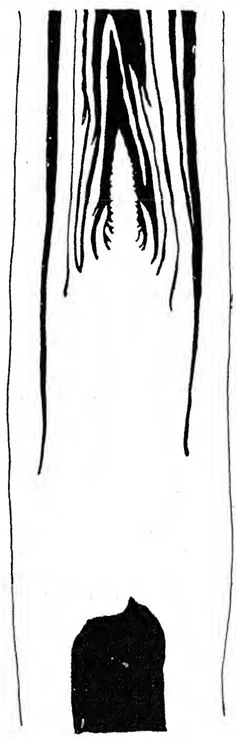


Fig. 69.—Longitudinal section through a young straw. Lengthening of the internodes just beginning (× 5).

The expansion of the straw proceeds from below upwards, the lowest internode being the first to lengthen (Fig. 69), the growth of this being followed more or less regularly by the succeeding internodes in numerical order to the sixth or uppermost; growth also ceases in the same order, the lower internodes reaching their full stature some time before the upper ones have arrived at their maximum length.

In the first table below is given the length of the ear, and the separate internodes of the straw from week to week, from the commencement of the "shooting" period to the time at which the straw reached its greatest height; in the second table the increase in length from week to week is recorded. As the stems are at first hidden by the surrounding leaf-sheaths and cannot be examined when young without destroying the plants, measurement of the growth of a single individual straw cannot be carried out. The figures from April 11 to May 30 are averages obtained from ten straws of similar size and development; those from June 6 onwards, however, refer to a single stem, the parts of which were clearly visible and easily measured after this date.

Table I

Length of the Straw and Ear of a Squarehead Wheat at Weekly Intervals from April 11 to June 27, 1914

Internodes.	1st.	2nd.	3rd.	4th.		5th.		6th.	Whole Straw.	Ear.
April 11	·25	·25	..	..	·2	..	..	..	·7	·15 cm.
,, 18	·35	·7	·2	..	..	·2	..	..	1·4	·2 ,,
,, 25	·3	2·0	·4	..	..	·3	..	..	3·0	·3 ,,
May 2	·4	2·6	1·4	·4	..	..	·2	..	5·0	·4 ,,
,, 9	1·3	5·5	4·0	·6	..	..	·2	..	11·6	·8 ,,
,, 16	3·4	8·1	11·3	2·6	..	..	·5	..	25·9	2·0 ,,
,, 23	3·4	8·5	12·7	6·6	..	..	·9	..	32·1	3·8 ,,
,, 30	3·4	8·5	15·3	18·0	..	8·2	..	3·8	57·2	7·8 ,,
June 6	4·2	..	16·0	21·0	..	21·5	..	8·0	..	8·2 ,,
,, 13	4·5	11·5	16·0	21·5	..	27·5	..	13·0	94·0	8·7 ,,
,, 20	4·5	11·5	16·0	21·5	..	30·1	..	21·0	104·6	8·7 ,,
,, 27	4·5	11·5	16·2	21·5	..	30·3	..	21·5	105·5	9·0 ,,
July 17	4·5	11·5	16·2	21·5	..	30·3	..	21·5	105·5	9·0 ,,

Table II

Amount of Increase in Length of the Straw and Ear from Week to Week (April 11 to June 27, 1914)

Internodes.	1st.	2nd.	3rd.	4th.		5th.		6th.	Whole Straw.	Ear.
April 11-18	·05	**.45**	..	..	·2	..	..	..	·7	·05 cm.
,, 18-25	·0	**1·3**	·2	..	..	·1	..	..	1·6	·1 ,,
,, 25-May 2	·1	·6	1·0	..	..	·3	..	..	2·0	·1 ,,
May 2-9	·9	2·9	**2·6**	·2	..	..	·0	..	6·6	·4 ,,
,, 9-16	2·1	2·6	**7·3**	2·0	..	..	·3	..	14·3	1·2 ,,
,, 16-23	·0	·4	1·4	**4·0**	..	..	·4	..	6·2	1·8 ,,
,, 23-30	·0	·0	2·6	**11·4**	..	11·1	..	..	25·1	4·0 ,,
,, 30-June 6	·8	..	·7	3·0	..	**13·3**	..	4·2	..	·4 ,,
June 6-13	·3	·3	·0	·5	..	**6·0**	..	5·0	12·1	·5 ,,
,, 13-20	·0	·0	·0	·0	..	2·6	..	**8·0**	10·6	·0 ,,
,, 20-27	·0	·0	·2	·0	..	·2	..	**·5**	·9	·3 ,,

The measurements indicate a wave of growth from the base to the summit of the stem. The greatest increase occurred in the second internode during the first two weeks, the greatest growth being transferred to the third internode in the fourth and fifth weeks, to the fourth in the next fortnight, to the fifth in the succeeding two weeks, and to the sixth in the last fortnight, at the end of which no further addition was made to the length of the stem or the ear.

The figures in the vertical columns of Table II. also show that in each internode and in the ear there is an acceleration to a maximum followed by a gradual retardation in the rate of growth.

The whole period of "shooting" occupied about eleven weeks, the greatest increase in length both of stem and ear occurring in the same week, namely, May 23-30.

At the time of its escape from the upper leaf-sheath in the week ending June 6 the ear had almost reached its maximum length, being then only 1 cm. shorter than the ear when full grown.

The escape of the ear from the uppermost leaf-sheath marks a definite and easily recognisable stage in the development of the wheat plant.

The date at which it occurs is dependent upon a number of factors, the chief of which are:

1. The race, variety, or form of the wheat.
2. The latitude and elevation of the place of growth.
3. The rainfall, temperature, light, and general climatic conditions of the season of growth.
4. The date at which the seed is sown.

Some Persian, Indian, Chinese, and Australian forms sown in September or October at Reading come into "ear" at the end of the following May, while many English wheats sown at the same time do not reach this stage of development until the second or third week in June.

The speed in attaining the "earing" stage, *i.e.* the "earliness" and "lateness" of a variety, is a constant hereditary character which exhibits the ordinary fluctuating variability, but is not permanently modified by sowing the grain early or late or by varying the external conditions of growth. Varieties preserve their characters in this respect no matter where they are cultivated; those which are relatively early or late in India or Australia are early or late when grown in England, and rapid or slow developing English forms exhibit the same relative differences when transferred to another country.

Schübeler and others have asserted that a "late" wheat can be transformed into an "early" one and *vice versa* by varying the date of sowing or by transference to another climate for a time; there is little doubt that a mixture of sorts was sown in such cases and the conclusions were illusory.

A "late" form is later in its ear production than an "early" form

when the two are sown together, no matter where or in what season the experiment is carried out, although, as mentioned hereafter (p. 91), the time required by a wheat to reach the "earing" stage may be 300-320 days or only 60-70 days according to the time at which its grain is sown.

Each form of wheat sown on a particular date in England shows remarkable regularity in the production of its ears: in normal seasons the latter frequently appear on the same day in each year, and only in years of drought or unusual rainfall is the time of their escape from the leaf-sheaths accelerated or retarded more than a week or ten days. The constancy of this character is of use in distinguishing closely allied forms, where these can be grown together and observations made during several seasons.

For purposes of description and classification wheats may be grouped into "early," "mid-season," and "late" forms, the former usually exposing their ears at Reading before the end of May, the latter during the second or third week in June.

In the following table is given the usual date of "earing" of over 1500 wheats when sown in September or October at the University College Farm, Reading:

		T. aegilopoides.	*T. monococcum.*	*T. hermonis.*	*T. dicoccum.*	*T. durum.*	*T. turgidum.*	*T. Spelta.*	*T. vulgare.*	*T. compactum.*	*T. sphaerococcum.*	Total.
Early—												
Very early.	May 14-24 .	..	..	2	..	15	..	..	33	5	6	61
Early.	„ 24-31 .	..	..	2	4	120	10	4	211	5	..	356
Mid-season—												
Mid-season.	June 1-7 .	..	..	2	..	94	50	3	528	24	..	701
Late—												
Late.	June 8-15 .	4	2	4	3	10	59	..	240	12	..	344
Very late.	„ 15-25 .	..	2	..	1	..	5	..	70	2	..	80
Total number of forms .		4	4	10	8	239	124	7	1082	48	6	1542

Although the date of "earing" of a wheat when sown at a particular time is almost constant, the exit of the ear from the leaf-sheath may be arranged to occur early or late over a fairly wide period of the summer by altering the time of sowing. If, however, it does not take place before the first week or ten days of July there is rarely sufficient time for the grain to ripen at Reading (see pp. 90-92).

In order to determine the variation which can be induced in this manner several wheats were sown at weekly intervals throughout the year ; in the following tables are given the results obtained with an early and one or two later forms sown in the first week of each month :

RED FIFE

Sown.	Ear out of Sheath.			Ear ripe.		Sowing to Earing.	Sowing to Ripe Ears.	Earing to Ripe Ears.
	1912.	1913.	1914.	1912.	1913.			
1912						days.	days.	days.
Feb. 24 .	June 15	..	..	Sept. 5	..	111	193	82
March 2 .	,, 15	..	..	,, 5	..	104	186	82
April 6 .	July 4	..	..	*	..	88	..	..
May 4 .	,, 18	..	..	*	..	74	..	..
June 1 .	Aug. 5	..	..	*	..	64	..	..
,, 15 .	,, 29	June 1	..	*	..	74	..	..
July 6 .	..	May 19	..	..	Aug. 8	317	398	81
Aug. 3 .	..	,, 20	..	..	,, 8	290	370	80
Sept. 7 .	..	June 7	..	..	,, 8	273	335	62
Oct. 5 .	..	,, 7	..	..	,, 9	245	308	63
Nov. 2 .	..	,, 10	..	..	,, 9	220	280	60
Dec. 7 .	..	,, 12	..	..	,, 12	187	248	61
1913								
Jan. 4 .	..	,, 18	..	..	,, 14	165	222	57
Feb. 1 .	..	,, 18	..	..	,, 18	135	198	63
March 1 .	..	,, 20	..	..	,, 20	111	172	61
April 5 .	..	July 1	..	..	,, 30	77	147	70
,, 19 .	..	,, 10	..	..	Sept. 18	72	152	80
May 3 .	..	,, 13	..	..	..	61	..	..
,, 10 .	..	,, 15	..	..	..	54	..	..
June 7 .	..	Aug. 12	June 3†	..	..	66	..	..
July 5 .	..	Sept. 10	? †	..	..	59	..	..
,, 12 .	..	..	May 25	..	..	317	..	..
Aug. 2 .	..	..	,, 25	..	..	296	..	..
Sept. 6 .	..	..	?	..	..	259	..	..
Oct. 4 .	..	..	June 3	..	..	242	..	..
Nov. 1 .	..	..	,, 8	..	..	219	..	..
Dec. 6 .	..	..	,, 14	..	..	190	..	..
1914								
Jan. 3 .	..	..	,, 16	..	..	164	..	..
Feb. 7 .	..	..	,, 20	..	..	133	..	..
March 7 .	..	..	,, 25	..	..	110	..	..
April 4 .	..	..	July 4	..	..	91	..	..
May 2 .	..	..	,, 14	..	..	73	..	..
,, 9 .	..	..	..	..	..	66	..	..
,, 16 .	..	..	..	..	..	63	..	..
							Average .	69·4

* Ears were produced in July and August, but these did not ripen in 1912, the summer months in that year being dull and wet.

† Ears were produced in August and September 1913, but did not ripen : the same plants lived through the winter and produced ears again in 1914.

This form may come into ear as early as May 19 or not until September 10, and may ripen its ear as early as August 8 or not until September 18. Ears which did not escape from the sheaths before July 10 had not time to ripen in that season and died off.

DAWSON'S GOLDEN CHAFF

Sown.	Ear out of Sheath.			Ear ripe.		Sowing to Earing.	Sowing to Ripe Ears.	Earing to Ripe Ears.
	1912.	1913.	1914.	1912.	1913.			
1912						days.	days.	days.
Feb. 24 .	June 29	..	..	Sept. 5	..	125	193	68
March 2 .	July 4	..	..	„ 17	..	123	198	75
April 6 .	Sept. 3	June 2	..	..	July 26	148	476	..
May 4 .	..	„ 4	..	..	„ 26	395	448	53
June 1 .	..	„ 5	..	..	„ 28	368	422	54
July 6 .	..	„ 5	..	..	„ 30	332	389	57
Aug. 3 .	..	„ 4	..	..	„ 31	303	362	59
Sept. 7 .	..	„ 4	..	..	„ 31	268	327	59
Oct. 5 .	..	„ 5	..	..	„ 31	241	299	58
Nov. 2 .	..	„ 7	..	..	Aug. 6	215	277	62
Dec. 7 .	..	„ 21	..	..	„ 8	194	244	50
1913								
Jan. 4 .	..	„ 20	..	..	„ 14	165	222	57
Feb. 1 .	..	„ 21	..	..	„ 20	136	200	64
March 1 .	..	„ 25	..	..	„ 25	116	177	61
„ 8 .	..	July 2	..	..	Sept. 6	116	182	66
April 5 .	..	Aug. 5	..	..	..	129	..	..
„ 19 .	..	..	June 2	..	..	409	..	..
May 3 .	..	..	May 30	..	..	392	..	..
June 7 .	..	..	„ 30	..	..	357	..	..
July 5 .	..	..	June 2	..	..	332	..	..
Aug. 2 .	..	..	May 30	..	..	301	..	..
Sept. 6 .	..	..	June 1	..	..	267	..	..
Oct. 4 .	..	..	„ 3	..	..	241	..	..
Nov. 1 .	..	..	„ 8	..	..	218	..	..
Dec. 6 .	..	..	„ 11	..	..	187	..	..
1914								
Jan. 3 .	..	..	„ 12	..	..	160	..	..
Feb. 7 .	..	..	„ 20	..	..	133	..	..
„ 28 .	..	..	July 2	..	..	..	..	..
March 7 .	..	..	„ 18	..	..	133	..	..
„ 14 .	..	..	„ 10	..	..	118	..	..
							Average .	60·2

This form may come into ear as early as May 30 or not until September 3, and may ripen its ears as early as July 26 or not until September 6. Ears which did not escape from the sheaths before the end of June or beginning of July had not time to ripen in that season and died off.

SWAN

Sown.	Ears out of Sheath. 1913.	Ears out of Sheath. 1914.	Ear ripe. 1913.	Sowing to Earing.	Sowing to Ripening.	Earing to Ripening.
1912				days.	days.	days.
Sept. 14 .	June 16	..	Aug. 16	275	336	61
Oct. 5 .	,, 19	..	,, 16	257	315	58
Nov. 2 .	,, 18	..	,, 18	228	289	61
Dec. 7 .	,, 21	..	,, 20	196	256	60
1913						
Jan. 4 .	,, 29	..	,, 30	176	238	62
Feb. 1 .	,, 30	..	Sept. 10	149	221	72
March 1 .	July 1	..	,, 12	122	195	73
,, 22 .	,, 17	..	,, 18	117	180	63
April 5 .	Aug. 10	..	*	127	..	..
May 3 .	..	June 7	..	400	..	..
,, 31 .	..	,, 7	..	372	..	..
June 28 .	..	,, 7	..	344	..	..
Aug. 2 .	..	,, 12	..	..	..	..
Sept. 6 .	..	,, 12	..	..	..	..
Oct. 4 .	..	,, 15	..	..	..	..
Nov. 1 .	..	,, 16	..	..	..	..
Dec. 6 .	..	,, 19	..	..	..	..
1914						
Jan. 3 .	..	,, 24	..	..	..	..
,, 17 .	..	,, 24	..	..	..	..
,, 31 .	..	,, 24	..	..	..	..
					Average .	63·7

* Did not ripen any ears in 1913.

SWAN

Sown.	Ear out of Sheath. 1916.	Ripe. 1916.
1915		
April 1	June 14 *	
,, 8	,, 14 *	
,, 15	,, 13 *	
,, 22	,, 13 *	
May 1		
,, 15		
June 1		
,, 15		
July 1	June 16-22	
,, 15		
Aug. 1		
,, 15		
Sept. 1		Aug. 14-19
,, 15		
Oct. 1	June 22	
,, 15	,, 24	
Nov. 1	,, 24	
,, 15	,, 24	
Dec. 1	,, 26	
,, 15	July 3	
1916		
Jan. 1	,, 4	
,, 15	,, 4	
Feb. 1	,, 5	Aug. 23
,, 15	,, 18	Sept. 3
March 1	,, 20	†
,, 15	,, 24	†
April 1	‡	..
,, 15	‡	..

* A few ears were produced in September and October 1915 by these plants, but most in June of the following season 1916.

† Ears were produced late in September, but did not ripen, and died off in 1916.

‡ These plants formed dense leafy tufts in 1916, from which were sent up a few culms late in September and October.

Sown before the end of February, this form produced ears which ripened in the same season: sown later than this, few or no ears were produced or ripened until the succeeding season.

BLUE CONE

Sown.	Ears out of Sheath.		Ears ripe.	Sowing to Earing.	Sowing to Ripening.	Earing to Ripening.
	1913.	1914.	1913.			
				days.	days.	days.
1912						
Oct. 12 .	June 21	..	Aug. 25	252	317	65
Nov. 2 .	„ 21	..	„ 30	232	301	69
„ 9 .	„ 21	..	Sept. 2	224	297	73
„ 23 .	„ 30	..	..	219	..	..
Dec. 7 .	?	..	Sept. 12	..	..	..
1913						
Jan. 4 .	?	..	„ 12	..	251	..
Feb. 1 .	?	..	„ 14	..	225	..
March 1 .	?	..	„ 18	..	201	..
„ 15 .	July 20	..	„ 20	..	189	..
April 5 .	Aug. 12	..	..	..	..	..
„ 12 .	..	June 7	..	421	..	..
May 3 .	..	„ 6	..	399	..	..
June 7 .	..	„ 7	..	365	..	..
July 5 .	..	„ 11	..	341	..	..
Aug. 2 .	..	„ 12	..	314	..	..
Sept. 6 .	..	„ 15	..	282	..	..
Oct. 4 .	..	„ 17	..	256	..	..
Nov. 1 .	..	„ 21	..	232	..	..
Dec. 6 .	..	„ 23	..	199	..	..
1914						
Jan. 3 .	..	„ 24	..	165	..	..
Feb. 7 .	..	„ 30	..	..	..	..
					Average .	69

This wheat may come into ear as early as June 7 or not until August 12, and may ripen as early or earlier than August 25 or not until September 20.

All wheats sown at Reading in January, February, and March produce ears in the same season; if sowings are made at weekly intervals later, there arrives a time which is too advanced to allow the growth of the plant to proceed as far as the "shooting" of its ears in that year. In the case of the early or rapid-growing "Fife" wheat this period is as late as July, while for late, slow-developing forms, such as Swan and Dawson's Golden Chaff, it is as early as the middle of April.

If sowing occurs after these critical periods, the plants grow and tiller extensively but do not "shoot"; they behave as if they had cognisance of the want of time to carry their development to the "earing" stage in that season, and remain short leafy tufts through the summer and succeed-

ing winter, sending up their stems and ears in the following year very little in advance of plants sown several months later.

The critical period is nearly constant for the same form ; there is indeed a certain degree of irregularity in the development of the plants sown about this date, some individuals sending up a few ears, while others refuse to do so entirely ; sown a week earlier or later, however, the plants exhibit a decision in their behaviour which is very striking.

For a time the young plants in successive rows grow and develop apparently at the same rate, but ultimately the earlier sown rows send up their stems and ears to a height of 3-4 feet, the neighbouring rows in which the sowing has been delayed but a week or ten days remaining a few inches high ; the contrast is remarkable in view of the small difference of time between the sowings and the apparently similar climatic conditions under which the plants are grown.

Fife wheat sown before the critical period—say in May—produces ears in 60-70 days, whereas it does not come into ear until about 300 days have passed when sown at the end of July or beginning of August. Similarly, later wheats may produce ears in 115-120 days, or not before the lapse of 400 days according to the time of sowing.

Fife wheat sown on May 10, 1913, was in ear in 54 days, *i.e.* on July 13.

The late form, Dawson's Golden Chaff, came into ear most rapidly when sown in March, the time between sowing and " earing " being 116 days.

When sown at the most favourable time certain wheats come into ear in 6 or 7 weeks, but forms with such power of rapid development are rare. A Chinese wheat from Newchwang sown on May 25, 1911, was fully in ear on July 8, or 44 days after sowing, and another from Fu-chia Chuang sown on May 18, 1916, came into ear on July 6, 49 days after sowing.

On the other hand, the latest forms do not come into ear in less than 150 to 160 days, even when sown at the most propitious date.

For each form of wheat there is a date before which ears are never produced when grown in the open field no matter at what time the grain is sown : it varies with the amount of light, mean temperature, and other climatic conditions of the place of growth.

At Reading the earliest date at which wheats can be made to come into ear is about the middle of May, and this is the case only with very early Chinese and Indian forms sown in autumn of the previous year.

The latest period at which ears escape from the leaf-sheath at Reading is some time during September or October, the exact date being subject to much more fluctuation than the time of the earliest appearance of ears. At such late season the " shooting " or expansion of the stems is very irregular, and only a few ears of each plant are pushed out ; these die off as the autumn advances and do not ripen grain.

During the cold autumn months wheat makes comparatively little growth, although the difference between plants of the same form sown in September and those sown in November, in respect of the number of shoots which they possess, is sometimes considerable. So far as the "shooting" and "earing" processes are concerned, they are evidently in much the same state of development, or very little in advance of each other, for observations of the growth of many varieties over several seasons show that rows of the same wheat sown during September, October, or November come into ear within 3-5 days of each other in the following June; also, those sown in January and February usually send forth their ears nearly together, although later than those sown in autumn.

Sown in January or February they send forth their ears later, the early sorts from 4 to 7 days, the later varieties as much as 10 to 20 days later than the same kinds sown in autumn up to November in the previous autumn.

Anatomy of the Culm and Rhizome

A culm or straw is composed of the following tissues:

(1) The epidermis; (2) the hypoderm or zone of mechanical tissue beneath the epidermis; (3) green assimilating parenchyma; (4) colourless ground parenchyma; and (5) the vascular bundles.

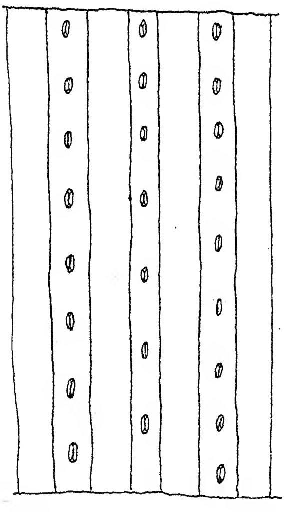


Fig. 70.—Lines of stomata of the culm (× 50).

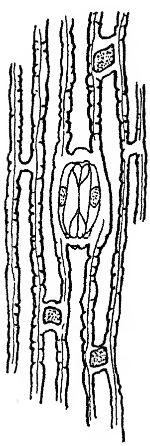


Fig. 71.—Epidermis of the culm (× 210).

In transverse section the straw is almost circular in most Bread wheats (*T. vulgare*), but in other races, especially *T. dicoccoides*, *T. turgidum*, and *T. polonicum*, the outline is wavy, the surface of the culm in these being more or less deeply furrowed.

(1) The epidermis, which is about 25-30 μ thick, is formed of narrow elongated cells 150-250 μ long, with short square cells 9-13 μ across intercalated among them at intervals. In wheats with the furrowed straws, short papillae or scabrid hairs are often present, particularly in the furrows. Single or double lines of stomata similar to those found on the leaf-blade and sheath are present (Fig. 70), the stomata being 200-250 μ apart in the row. The cells over the hypoderm

are about 4 μ in diameter, those covering the green assimilating tissue being wider (10-15 μ in diameter) with more sinuous walls.

The walls are all pitted and extensively thickened, and on the parts not hidden by the leaf-sheath a cuticle is present, the surface of which in the case of glaucous-stemmed varieties is covered with minute flaky particles of wax.

(2) The hypoderm is a strong elastic cylinder of mechanical tissue, consisting of lignified fibres with narrow lumina and strong walls about 4 μ thick: in a transverse section of the straw it appears as a continuous zone of cells immediately within the epidermis, and is of variable thickness, being more or less wavy in outline on its inner side (Figs. 72, 73).

From the measurement of a full-grown straw of "Squarehead" wheat given on p. 64, it is seen that the average thickness of the zone is about

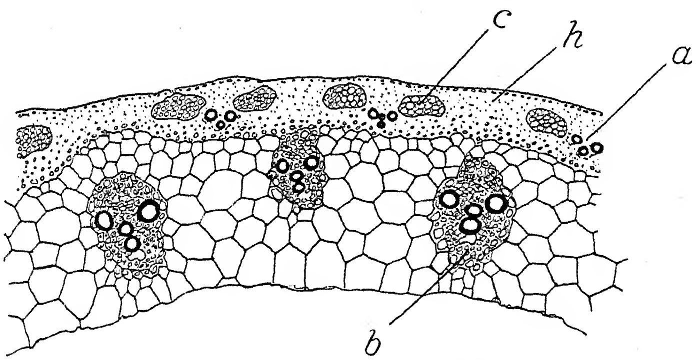


FIG. 72.—Transverse section of portion of the culm (lower part of the upper internode) ($\times 70$). *a*, Small vascular bundle in the hypoderm (*h*); *b*, large vascular bundle; *c*, band of chlorophyllous tissue.

the same in the 2nd, 3rd, 4th, and 5th internodes; in the upper internode it is slightly stronger, and reaches its greatest development in the lowest section of the straw.

A similar relationship in regard to the thickness of this zone of supporting tissue is seen in each of the separate internodes, being stoutest in the basal and thinnest in the middle portions.

(3) The assimilating tissue of the stem resembles that of the leaf, consisting of delicate parenchymatous cells, which in longitudinal view are irregular in form, but in transverse section are almost circular and about 12 μ in diameter (*c*, Fig. 73). It is imbedded in the sclerenchymatous hypoderm, but a portion of its outer face is always in immediate contact with the epidermis, through the stomata, by which it is brought into communication with the atmosphere.

The tissue is arranged in parallel bands, which appear as narrow green strips along the stem, with lines of colourless stereome between. The

bands frequently run in pairs, which sometimes coalesce to form broader

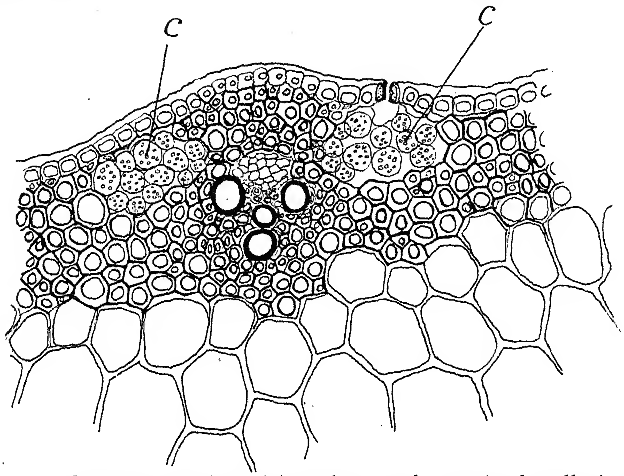


Fig. 73.—Transverse section of hypoderm and vascular bundle (×380).
c, Bands of chlorophyllous tissue.

ones. Each band is wide at the apex and tapers gradually as it is traced

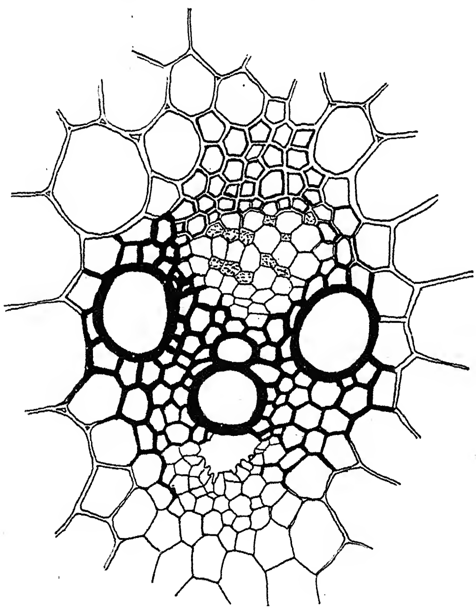


Fig. 74.—Transverse section of large vascular bundle (×260).

downwards; beneath the leaf-sheath it diminishes rapidly, and finally disappears before it reaches the base of an internode.

The average width and thickness of each individual band is greatest

in the upper internode, and the bands are closer together there, giving this portion of the straw an almost uniformly green tint; in the three lowest internodes the tissue is only found in the upper parts, and is much reduced, or entirely absent, at the bases.

(4) The colourless ground parenchyma extends from the hypoderm to the centre or to the hollow pith-cavity found in most wheats. It is composed of thin-walled, finely-pitted cells polygonal or rounded in section, those bordering the stereome being long and narrow (350 μ long, 35 μ in diameter), nearer the centre they are shorter and wider (150-250 μ long and up to 100 μ in diameter); they soon die and lose their cell-contents.

In the lowest internodes the walls of the parenchyma become thickened and lignified; the tissue then materially assists the hypodermal stereome in strengthening the base of the straw. Very thick-walled ground parenchyma is found also in the lower part of the solid diaphragm between the internodes, forming a lining to the upper part of the hollow pith-cavity.

(5) In a transverse section through the hollow internode the vascular bundles are found distributed symmetrically in the wall of the straw. Imbedded in the hypoderm is a ring of very small bundles separated from each other by somewhat wide intervals, each bundle being placed between two green lines of assimilating tissue (*a*, Fig. 72).

Nearer the centre, in the soft parenchyma, are the large bundles of the stem, arranged more or less regularly in a ring, with an occasional bundle of intermediate size close to the inner edge of the hypoderm.

The large bundles are of the usual closed collateral type, with the xylem directed towards the centre of the stem, its chief vessels arranged in the form of a V.

The protoxylem forming the apex of the V consists of one or two annular or spiral vessels; two pitted vessels with wider lumina are situated on the right and left limbs of the V, the space between the chief vessels being occupied by small tracheids.

The phloem of the bundle lies between the open limbs of the V and extends slightly beyond it. It is composed of sieve-tubes with their companion-cells.

Surrounding each large bundle is a sheath of fibrous stereome, which in the case of the small hypodermal bundles is not differentiated from the stereome in which they are imbedded.

The bundles of the leaf-sheath curve inwards into the node and pass through the latter as separate isolated strands without fusing with each other or with the neighbouring bundles which have come from the internode above.

In the leaf-sheath itself all are of somewhat similar diameter, but in traversing the node approximately half of them become very much thickened, and alternate in more or less regular order with the other half,

which are reduced in diameter : the finer strands pass into the hypodermal stereome ring of the stem, or close to it, the larger ones arranging themselves nearer the centre in the pith of the straw.

Of the 30 bundles in the leaf-sheath illustrated in I., Fig. 75, 13 (Nos. 1, 3, 5, 7, 10, 12, 14, 16, 18, 20, 23, 27, and 29) go through the node into the hypodermal stereome of the stem or near it (VI., Fig. 75), the remaining larger strands (17) going into the pith.

The small unnumbered hypodermal bundles seen in the section of the stem (VI., Fig. 75) arise within the stereome of the leaf-sheath bundles a short distance above the node (*x*, Fig. 75).

In the internodes of the stem the bundles run longitudinally in parallel lines ; traced downwards, they are found to enter the solid node. Just below the point of junction of the leaf-sheath the fine hypoderm bundles curve outwards, some of them at the same time spreading more or less horizontally and uniting with each other to form a narrow more or less broken ring (*r*, II., Fig. 75). A little lower the stouter, inner, larger cauline bundles bend outwards and insinuate themselves between the large leaf-traces, at the same time bifurcating or fusing with each other in an irregular manner, some of the strands twisting and curling through the central pith in various directions, others passing out into the cortical parenchyma on the outer margin of the zone of large bundles.

The 37 " pith " bundles of the stem (I., Fig. 75) found above the node are reduced by fusion and anastomosis within the node to 16, which are seen (not numbered) in the section of the stem below the node (VI., Fig. 75), alternating more or less regularly with the 17 large bundles which have come from the leaf-sheath.

Generally in a section of an internode of a straw all the fine bundles in the hypoderm and a few small bundles near it come from the leaf-sheath immediately above ; of the larger bundles within the pith, about one half come from the leaf-sheath, the other half descending through the node from the internode above.

In a transverse section the bundles in the leaf-sheath appear of the ordinary collateral type with girders of stereome connecting them with the outer epidermis (2, Fig. 57). Very near the base of the sheath, however, the stereome strands are free from the epidermis, each becoming oval in section (1, Fig. 57) : imbedded within them are the rudiments of minute bundles (usually one but sometimes two in each) the first traces of which consist of two or three leptome cells.

On entering the node the stereome strand is reduced and finally disappears : the minute bundle within the latter becomes more clearly defined and can be traced through into the hypoderm of the stem below.

As previously mentioned, some of the leaf-sheath bundles on entering the node are reduced in size, but about half of them are greatly increased

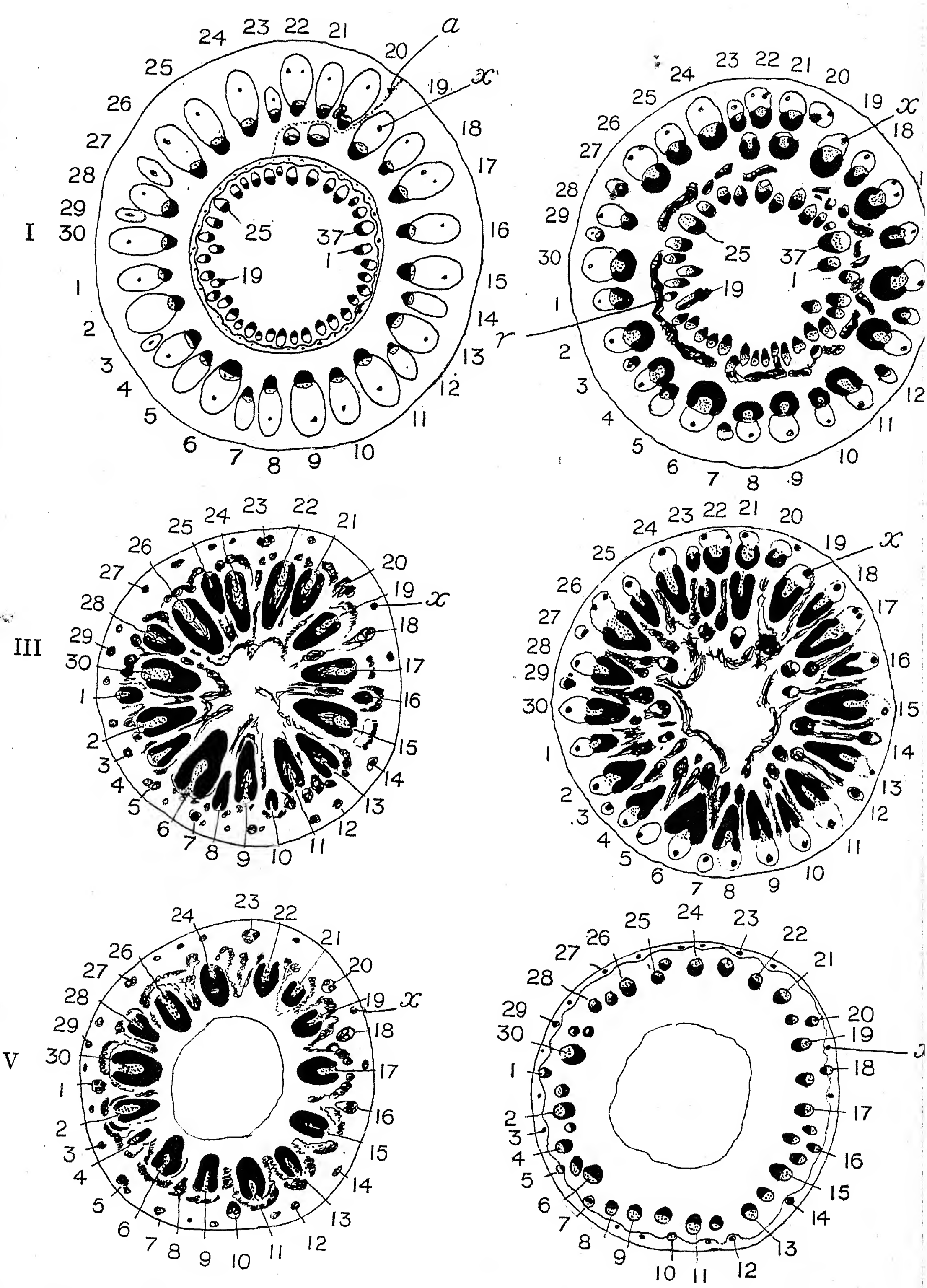


FIG. 75.—SUCCESSIVE TRANSVERSE SECTIONS THROUGH THE LEAF-BASE AND NODE OF A CUL[illegible]
illustrating the [illegible]

in diameter and form a conspicuous ring of strands, each of which is flattened laterally, becoming oval or pear-shaped in section (Fig. 75).

Around the bundle, in its course through the node, is a sheath of parenchyma containing many green chloroplasts.

The xylem elements of these large sheath bundles are much increased within the node, the vessels being replaced by a great many short, pitted and reticulately thickened tracheids of small diameter distributed irregularly with xylem parenchyma.

In the lower section the xylem elements more or less completely encircle the bast, but this amphivasal arrangement is lost after the bundles leave the node, and the collateral form is soon resumed.

In the internode above and below the node the cauline bundles are of the ordinary collateral type, but within the node they are much changed in structure; the sheath of sclerenchyma on the pith side is somewhat strengthened and the vessels become more numerous, the typical V-shaped section being altered to a Y, the stem of which is formed of 4 to 6 vessels of more or less elliptical section. Lower, the vessels on the arms of the V and Y are replaced by groups of short tracheids.

The number of bundles in a straw varies considerably, stout straws of plants grown wide apart possessing more than those of crowded crops; in the early developed stems of tillered plants the bundles are more numerous than in straws formed later.

The total number is generally greatest in one of the two uppermost internodes, but sometimes in the lowest, fewer being found in the intermediate portion of the straw.

In the first four internodes there are usually more in the inner zone of large bundles than in the hypoderm, but in the portion of the stem immediately below the ear the reverse is occasionally the case.

On the following page are given the numbers of the vascular bundles in the internode of the 6 straws of a plant of *T. vulgare* (Squarehead) from a row of plants grown 3 inches asunder in rows 1 foot apart.

The thin rhizomatous portion of the stem between the grain and the tillering nodes is about ·6-1 mm. in diameter. Its anatomy is somewhat different from that of the internodes above ground, there being a clearly circumscribed stele or central cylinder surrounded by a soft thin-walled cortex. The epidermis consists of elongated parenchymatous cells about 7 μ in diameter, with thin walls; hairs and stomata are absent. Within, is the cortex of thin-walled parenchyma, generally 6 to 8 cells deep and about ·15-·16 mm. across; there is no zone of hypoderm, but occasionally one or two very fine strands of stereome are seen just beneath the epidermis. A fairly well-defined endodermis is visible, differentiated from the rest of the cortical tissue by its thick inner walls, which are lignified and show lines of stratification.

No. of Internode.	Length of Internode (Inches).	No. of Bundles.		Total.	No. of Internode.	Length of Internode (Inches).	No. of Bundles.		Total.
		Hypoderm Ring.	Inner Ring.				Hypoderm Ring.	Inner Ring.	
	STRAW 1.					STRAW 2.			
6th	18·5	38	34	72	6th	18·9	34	31	65
5th	11·3	34	43	77	5th	10·9	35	35	70
4th	6·2	28	44	72	4th	6·8	26	36	62
3rd	3·7	22	41	63	3rd	3·6	21	41	62
2nd	2·9	22	36	58	2nd	2·6	18	38	56
1st	1·3	30	33	63	1st	1·2	19	33	52
Total	43·9	Av. 34·8	38·5	67·3	Total	44·0	Av. 25·5	35·6	61·1
	STRAW 3.					STRAW 4.			
5th	18·8	35	32	67	5th	17·7	35	31	66
4th	10·5	35	34	69	4th	10·5	31	34	65
3rd	4·6	25	38	63	3rd	4·9	24	35	59
2nd	2·7	20	38	58	2nd	2·6	19	35	54
1st	1·4	22	36	58	1st	1·5	23	34	57
Total	38·0	Av. 27·4	35·6	63	Total	37·2	Av. 26·4	33·8	60·2
	STRAW 5.					STRAW 6.			
5th	13·7	32	30	62	5th	8·7	25	26	51
4th	8·7	29	32	61	4th	7·7	24	33	57
3rd	5·0	24	34	58	3rd	5·3	19	33	52
2nd	2·8	19	36	55	2nd	2·9	17	34	51
1st	1·0	21	41	62	1st	·9	19	37	56
Total	31·2	Av. 35·0	34·6	59·6	Total	25·5	Av. 20·8	32·6	53·4

The following are the numbers of the vascular bundles in the leaf-sheaths and internodes of a full-grown straw of *T. vulgare* (Squarehead) taken from an ordinary field crop.

Leaf-sheaths.		Straw.				
	No. of Bundles.	Internode.	Bundles in Hypoderm Ring.		Bundles in Inner Ring.	Total.
5th	35	5th (upper)	top	24	22	46
			middle	27	24	51
			base	24	24	48
4th	38	4th	top	28	31	59
			middle	28	31	59
			base	29	31	60
3rd	25	3rd	top	18	31	49
			middle	18	32	50
			base	18	32	50
2nd	23	2nd	top	16	34	50
			middle	16	34	50
			base	16	34	50
1st	..	1st	top	22	34	56
			middle	22	37	59
			base	22	37	59

The stele from ·5 to 6 mm. in diameter occupies the centre of the rhizome, and near its periphery are the vascular bundles, generally 10-15 in number, distributed somewhat irregularly in one or two zones, the larger bundles to the outside.

Each bundle is usually of the ordinary collateral type with V-shaped xylem and a narrow sheath of sclerenchyma. Some of them have only one large vessel ; in others, two vessels are present, these being irregular in size and not arranged symmetrically. The centre of the cylinder, though sometimes hollow, is more often filled with soft pith.

CHAPTER VII

THE INFLORESCENCE

THE inflorescence or ear of wheat is a distichous compound spike, the primary axis bearing two opposite rows of lateral secondary spikelets and a single fertile terminal spikelet, except in the case of *T. monococcum* in which the latter is rudimentary and barren, or missing.

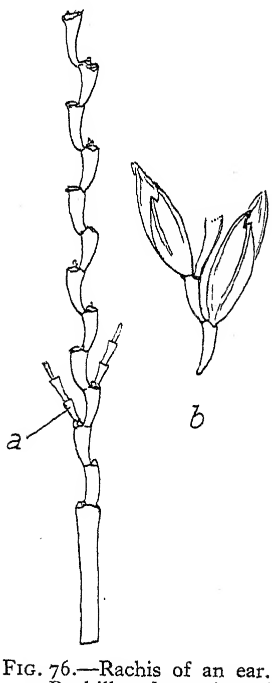


FIG. 76.—Rachis of an ear. *a*, Rachilla ; *b*, portion of rachis with attached spikelets.

The main axis or rachis is a sinuous notched structure composed of a number of short internodes (Fig. 76), which in the "Spelt" wheats *T. aegilopoides*, *T. monococcum*, *T. dicoccoides*, and *T. dicoccum* disarticulate easily at each node when the ear is ripe (Fig. 77), and in *T. Spelta* breaks transversely just below each spikelet (Fig. 207). In the majority of cultivated wheats, however, the rachis is tough and resists disarticulation or breaking even when thrashed.

Each short segment of the axis is narrow at the base and broader at the apex, one side of it being more or less convex, the other flattened or slightly concave. Its lateral edges are fringed with hairs of variable length, and there is usually a larger or smaller tuft of hairs—the frontal tuft—at the apex of the convex side between the two lowest glumes of the spikelet. All the spikelets are sessile ; the lateral ones are ranked alternately on opposite sides of the rachis, each being placed at the apex of an internode, with its broadside towards the flat or concave surface of the segment immediately above its point of insertion.

The terminal spikelet is arranged at right angles to the rest.

Great variety is found among wheats in respect of the number of spikelets per unit length of the rachis. In some, the spikelets are crowded together, the lengths of the internodes between each being very short

and hidden from view ; in others, they are widely separated and the rachis visible between the adjacent spikelets (cf. Figs. 188 and (1) 180).

In the majority of varieties the distribution of the spikelets along the rachis is fairly uniform, but in some ears the spikelets are especially crowded at the tip and arranged in a lax, open manner towards the base (1, Fig. 189); such ears are spoken of as "clubbed," though the name "Club wheat" is used for the race *T. compactum*, in which the ears are very short, with spikelets closely set along the entire length of the rachis.

Viewed from the side the spikelets stand out from the rachis, making with the latter an angle of 20°-80° or more, the smaller angle being found in lax-eared forms, the larger in dense compact ears.

Each spikelet consists of a delicate flattened and jointed rachilla (*a*, Fig. 76) which bears two opposite rows of alternate solitary flowers hidden between chaffy bracts or glumes. The glumes are either glabrous or covered with soft hairs, the colour when ripe being creamy white, yellow, red, brown, or black.

The number of flowers in a spikelet varies from 3 to 9, of which one or more of the upper ones are usually imperfect and sterile.

At the base of the spikelet are two opposite rigid boat-shaped bracts, the empty glumes, which in all wheats, except *T. polonicum*, are shorter than the rest of the spikelet, and in lateral spikelets the parts right and left of the midrib are dissimilar in size and shape. Their size, shape, texture, form of keel, and terminal tooth are constant characters, of high taxonomic value. In some wheats they are keeled throughout their whole length, in others the projecting keel extends only a short distance from the apex, the lower portion being rounded; each possesses several nerves, the central strongest one dividing the glume into two unequal halves, of which the outer is the broader.

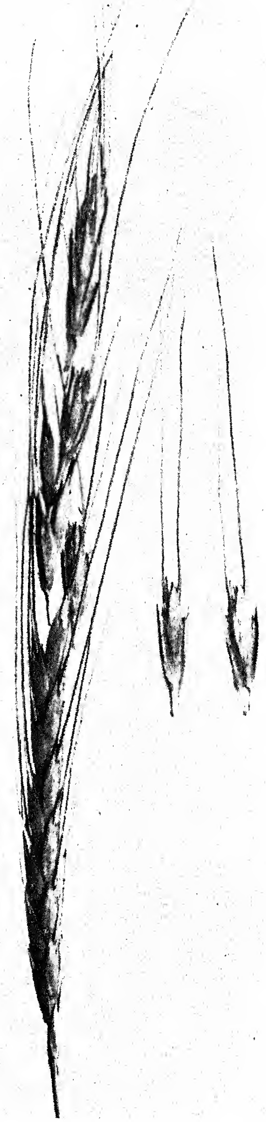


FIG. 77.—Disarticulation of the rachis of a form of *T. aegilopoides*.

The form of the apex of the empty glume differs considerably in the various kinds of wheat; in some it is broad with a blunt extension of the midrib, in others it is narrower with the central nerve continued into an acute point; in certain forms of *T. vulgare* and *T. compactum* from Central Asia it possesses a terminal scabrid awn from 2 to 5 cm. long, but in the majority of wheats the terminal tooth or keel is not more than a few millimetres in length.

In *T. aegilopoides* and *T. monococcum* the empty glume has a lateral secondary tooth on its broad outside half, in addition to the primary central one; in most other wheats the secondary tooth is short or altogether absent.

The empty glumes of the terminal differ from those of the lateral spikelets; they are rarely keeled and always symmetrical, a line down the centre dividing them into two similar halves. In some wheats these glumes have single, well-defined midribs; in others the midrib is missing, in which case two strong lateral veins are present, one on each side of the central line, the apex being notched or divided sometimes to near the base of the glume (Fig. 78).

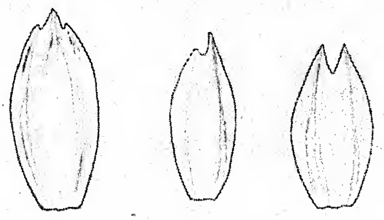


FIG. 78.—Empty glumes (*T. turgidum*) (× 3). *a* and *c*, from terminal spikelet; *b*, from a lateral spikelet.

The colour of the glumes is white, red, or black, but of each of these tints there are many shades. Whatever the natural hereditary tint, its full development is dependent largely upon the intensity of the light, heat, and atmospheric moisture during ripening. In certain varieties of *T. dicoccum*, *T. durum*, and *T. turgidum* the tint is a creamy white, but in the majority of the white-chaffed varieties it is pale yellowish; in a few Persian forms the glumes are a clear canary-yellow colour, and occasionally pale emerald green.

Among red-chaffed wheats the range is very wide, extending from the palest shades of red through deeper tints of brick-red to dark chestnut and sooty brown.

Black-chaffed varieties are comparatively rare, although examples are met with in all the races of wheats. Several shades are included under the term "black." In some glabrous forms the chaff is almost jet black, in others a dark sooty brown; these colours when overlaid by a pale waxy covering or a felt of soft hairs are modified to bluish black or mouse-grey tints.

In most black-chaffed wheats the colour is only developed to its

full extent on exposed parts of the ear, the portions of the flowering glumes covered by the empty glumes being pale red or light yellow.

Among certain forms of *T. dicoccoides*, *T. aegilopoides*, and *T. durum* hybrids the colour is more or less irregularly distributed in lines or patches over the empty glume; in others it appears only as a single dark line along the outer margin of the glume, the latter character being conspicuous in some forms of *T. turgidum*, var. *melanatherum*, and in many hybrids of *T. dicoccoides*, *T. dicoccum*, and *T. durum*.

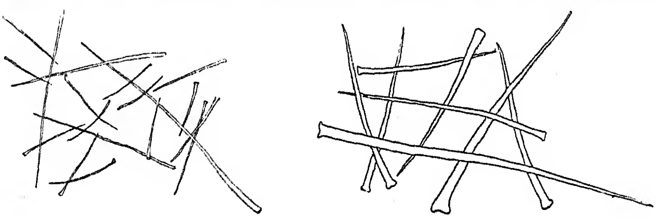
It is only in hot, bright seasons that the melanotic pigment is fully developed; in cooler damp years the glumes of black-chaffed varieties, especially those belonging to *T. vulgare* and *T. Spelta*, are generally an ashy-grey tint.

The glumes are either glabrous or more or less clothed with hairs. Sometimes the hairs are few and confined to the nerves, but in many forms they cover the whole surface with a tomentum or felt of varying density. The hairs are unicellular and terminate in a fine point.

In *T. aegilopoides* and *T. monococcum* the hairs are very slender, from ·16 to ·32 mm. in length, and of nearly uniform diameter. Both long hairs and short ones, about one quarter the length, are found on the glumes of *T. dicoccoides* and *T. dicoccum*. the long ones measuring from ·5 to ·65 mm., the short ones averaging about ·12 mm.

Similar slender silky hairs of two fairly distinct sizes occur on the chaff of *T. durum* and *T. turgidum*, the long ones being ·6-·8 mm. in length, the shorter only ·16-·2 mm. in *T. durum*, and ·2-·32 in *T. turgidum* (*a*, Fig. 79).

The hairs on the glumes of the pubescent varieties of typical *vulgare*



a *b*

FIG. 79.—Hairs from the glumes of (*a*) *T. durum*, (*b*) *T. vulgare* (×40).

wheats vary also in length, but the difference between the long and the short ones is not so great as in the races of wheats already mentioned; moreover, they are readily distinguished by their stouter appearance, greater width, and thicker walls (*b*, Fig. 79). The long hairs usually measure from ·6 mm. to 1·2 mm. in length, the short ones from ·2 mm. to ·3 or ·4 mm.

In some *vulgares*, typical stout *vulgare* hairs are found mixed with fine, slender, short ones, resembling those of *T. durum*, a similar mixture

being seen also in some forms of *T. polonicum*. The hairs of *T. Spelta* in some cases are stout, and of nearly uniform size ·4-·6 mm. long; in a few forms, stout hairs ·4 mm. long are mixed with stout short ones ·12 mm. long.

In dimensions the hairs on the glumes of *T. compactum* agree somewhat closely with those of *T. turgidum*.

Inserted alternately on opposite sides of the short rachilla are the flowering glumes, in the axils of which the flowers arise. They are boat-shaped, many-nerved, and without keels, the upper part notched and ending in a point or a long awn, the length of which usually increases in the spikelets near the tip of the ear.

The awns are tapering and triquetrous, with forward pointing scabrid projections running longitudinally along the angles; they are generally straight, but may be sinuous or even bent into the form of a hook or spiral, as in some Asiatic forms of *T. vulgare*. In a Persian form of *T. vulgare* the awn has a pair of thin membranous and colourless outgrowths (Fig. 217).

The separation of wheat into "bearded" and "beardless" kinds was made as soon as the classification of the cereal was attempted, the two groups being characterised respectively by the presence or absence of a long beard or awn on the flowering glumes of the ear.

In the bearded wheats, long awns occur on the flowering glumes of all the spikelets from the base to the tip of the ear, the longest being a little above the middle of the ear, the shortest at the base and apex. The two lower flowering glumes of each spikelet have awns nearly equal in length and fully developed, the third and succeeding glumes having shorter awns which are frequently reduced to a fine point, especially when the subtended flower produces no grain.

Strictly beardless wheats entirely without awns are of exceptional rarity. I have met with them only in a small group of Indian, Japanese, and Australian forms of *T. vulgare*, which I have little doubt are genetically related; in these, the flowering glume terminates in a short tooth, like that of the empty glume

The term "beardless" is, however, used not only for those wheats in which awns are altogether absent, but for many hundreds of forms having short points or greatly reduced awns, usually not more than 1 cm. in length, confined to the tip of the ear. In a small percentage of cases one or two awns on the terminal spikelets reach a length of 2·5 cm., but the difference between bearded and beardless varieties is fundamental, and there is no difficulty in assigning any ear to one or other of these two classes, except, perhaps, in the case of rare, unstable hybrid forms in which awns of intermediate length sometimes appear over a considerable length of the ear.

In truly bearded ears the awns are uniformly distributed from the top

to the bottom of the ear with the longest never at the apex, while in beardless ears whatever awns are present are longest near the apex of the ear, the rest rapidly diminishing in length towards the base, where they are rarely more than 1-3 mm. long.

Beardless forms are not found in *T. aegilopoides*, *T. dicoccoides*, *T. monococcum*, *T. orientale*, and *T. pyramidale*, and are of great rarity in *T. dicoccum*, *T. durum*, *T. turgidum*, and *T. polonicum*, but among the remaining races, viz.: *T. vulgare*, *T. compactum*, *T. sphaerococcum*, and *T. Spelta*, both classes are equally common, almost all the bearded varieties of these wheats having a corresponding beardless representative.

The awns are white, red, or black, those of the two former tints being found only on white or red glumes respectively; black awns are met with on glumes of all colours, white, red, or black.

Varieties with black awns are seen among all races of wheat, but are most common in *T. durum* and *T. turgidum*. They are exceptionally rare in *T. vulgare*. I have seen but few examples of typical ears of the latter race with jet-black awns; these came from Asia Minor and Central Asia. The black pigment is always most conspicuous in specimens grown in bright hot climates.

In some wheats the black colour is almost constant under a wide range of climatic conditions; in others, it is dependent on the intensity of the light, heat, and moisture at the time of ripening. In cool, damp seasons the black pigment in the latter forms never develops, but returns in hotter years. This variation I have repeatedly observed in the progeny of single ears, perhaps more especially in forms of *T. durum*, var. *melanopus*, and similar results have been recorded by Metzger, Koernicke, Howard, and others in different varieties. Such variation greatly reduces the taxonomic value of black awns.

The fact that external conditions of soil and climate greatly influence the development of pigment in the awn complicates the problem of its inheritance.

Opposite each flowering glume, but attached to the very short floral branch with its back to the rachilla is the palea, a symmetrical thin membranous glume with two prominent lateral veins, along which runs a line of stiffish hairs; the part between the veins is concave and the two semi-transparent margins curve inwards round the flower.

Structure of Rachis, Glumes, and Awns

The rachis is notched, consisting of short internodal lengths, each of which is convex on one side and more or less flattened on the other; the lower internodes are somewhat semicircular in transverse section, the upper ones flattened and spindle-shaped in section (Fig. 80).

The structure resembles that of the internodes of the culm. On the outside is an epidermis of oblong cells, their length from 6 to 10 times their breadth, with sinuous thickened walls and oval or kidney-shaped "dwarf" cells alternating with them. At the edges are unicellular epidermal hairs of variable length.

Lines of stomata resembling those of the stem occur in the epidermis overlaying the longitudinal bands of chlorophyllous parenchyma which are found just beneath the epidermis on the convex side only. These

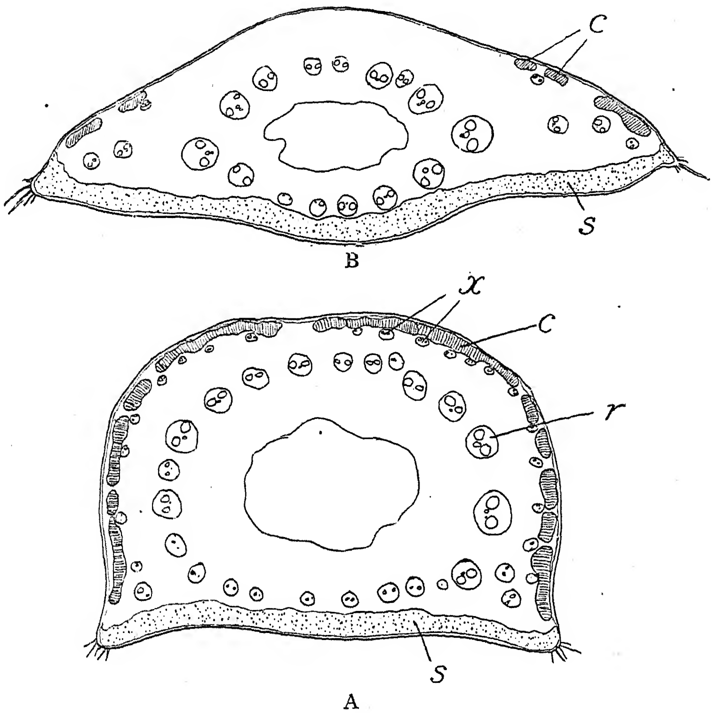


FIG. 80.—Transverse sections of the rachis (× 25). A, a lower internode ; B, an upper internode ; *s*, stereome ; *c*, chlorophyllous tissue ; *r* and *x*, vascular bundles.

green bands are most abundant in the lower internodes of the rachis (*c*, Fig. 80), being reduced to two or three narrow lines near the edges in the upper portions. Within the epidermis on the flatter side of each internode of the rachis which is hidden by the back of each spikelet there is a continuous band of stereome (*s*, Fig. 80).

The central part of the rachis is more or less completely filled with thin-walled ground parenchyma, imbedded in which are numerous vascular strands, the larger ones arranged in a circle or ellipse, the smaller bundles being found close to the inner side of the chlorophyllous bands.

The rachilla is delicate and flattened with an arrangement of tissues similar to that found in the rachis. The epidermal cells have straight walls not greatly thickened.

Numerous hairs are usually present.

There are generally three slender vascular bundles running through the thin-walled ground tissue.

The structure of the empty and flowering glumes resembles that of the ordinary leaf-sheath.

The outer epidermis of the empty glume consists of rows of oblong cells 80-100 μ long and about 25 μ broad, with oval kidney-shaped "dwarf" cells 16×25 μ between them at short intervals. The walls of these cells have characteristic wavy thickenings and simple pits (Fig. 81). The margins of the glumes are fringed with hairs, and trichomes of variable length are present on the outer surface, some being only short thick-walled papillae about 16 μ high.

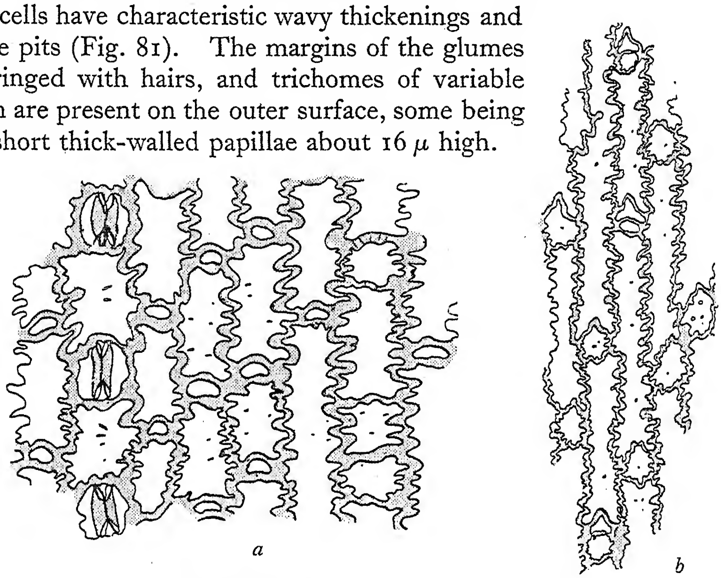


FIG. 81.—*a*, Epidermis of empty glume; *b*, of palea ($\times 210$).

Hairs are also found sometimes on the inner epidermis of the glume.

Rows of stomata occur especially in the apical region of the glume.

The cells of the inner epidermis have thinner walls; a few stomata are seen, and numerous hairs 50-70 μ long are also found on the inner surface, especially in the parts over the midrib and stronger nerves of the glume.

Narrow longitudinal green bands of thin-walled parenchymatous tissue accompany the vascular strands; the rest of the ground tissue has thickened walls. Delicate vascular bundles traverse the glume longitudinally and anastomose near the apex, the midrib strand terminating in the apical tooth.

The tissues of the flowering glume are similar in many respects to those of the empty glume; stomata and hairs occur on both surfaces.

In transverse section it is seen that near the margins of the glume the space between the outer and inner epidermis is occupied by strong thick-walled ground tissue traversed by vascular bundles and narrow longitudinal bands of assimilating tissue which lie close to the outer surface.

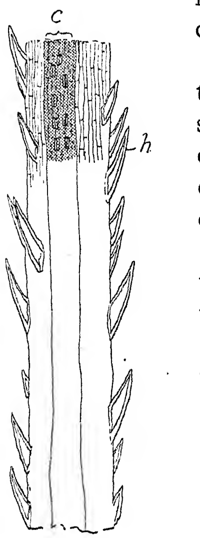


FIG. 82.—Portion of an awn of *T. turgidum* (× 35). *c*, Band of chlorophyllous tissue; *h*, scabrid hairs.

Away from the margins the glume is thinner and the stereome extends only to the middle of the section, the inner half consisting of thin-walled chlorophyllous parenchyma covered by an epidermis of larger thinner-walled cells than those on the outside of the glume.

A number of vascular bundles run from the base to the tip in bearded glumes; the central one and two of the lateral strands are continued into the awn.

The awn tapers from the base to the tip, and is triangular in section, the sides approximately equal.

One of the sides is parallel to the flattened rachilla and is continuous with the inner surface of the glume to which the awn belongs, the two other sides corresponding to the outer surfaces of the right and left halves of the glume.

The epidermis is composed (1) of narrow elongated cells with walls showing wavy thickening and numerous simple pits, (2) small oval or squarish "dwarf" cells often projecting as papillae, and (3) short thick-walled unicellular hairs with fine points which are directed forwards and give the awn its scabrid character (*h*, Fig. 82). In the epidermis on the two outer faces of the awn are longitudinal lines of stomata which communicate with green assimilating tissue within. The latter consists of two separate bands of chlorophyllous parenchyma,

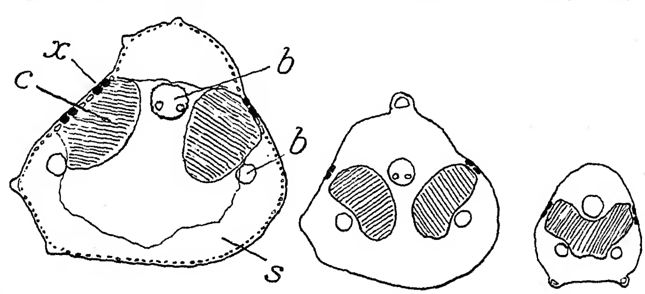


FIG. 83.—Transverse sections of an awn of *T. turgidum* (× 50). A, Near the base; B, at the middle; C, near the apex; *s*, stereome; *c*, chlorophyllous tissue; *x*, stoma; *b*, vascular bundles.

which traverse the awn from the base to near the apex, where they unite into a single central strand.

Immediately within the epidermis, at the three angles and around the inner face of the awn, is strongly developed stereome, the centre being occupied by thinner-walled parenchyma.

Three vascular strands are found in each awn, namely, one large bundle in the angle between the two bands of green tissue and continuous with the midrib of the glume, and two smaller ones right and left of this also entering from the glume (Fig. 83).

The palea is of simple structure and between the two keels is only two or three cells thick (about 30 μ). The epidermis is chiefly composed of elongated cells and circular " dwarf " cells with sinuous walls ; over the keels, the margins and surfaces of the apical portions of the palea it possesses hairs 50-130 μ long.

A simple vascular bundle runs through the centre of each keel ; associated with it is a small band of green parenchyma, chloroplasts being absent from other parts of the palea.

A few stomata are found over the green tissue.

CHAPTER VIII

THE FLOWER: FERTILISATION AND DEVELOPMENT OF THE GRAIN

IMMEDIATELY within the flowering glumes are two minute antero-lateral scales, the lodicules, which probably represent a small divided glume, although they are sometimes regarded as rudimentary perianth leaves. They are thin and colourless, about 1 mm. long, ·7-·8 mm. wide near the top, and ·4-·5 mm. at the base, with long hairs on the upper margin; at the flowering period they swell enormously, becoming for a short time more or less spherical, resembling pellucid drops, pushing apart the glumes and exposing the stamens and stigmas of the flower; later, they collapse and the glumes close again.

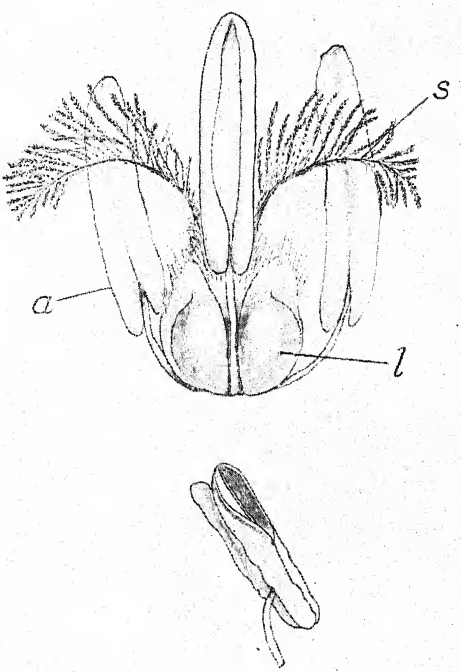


FIG. 84.—Flower before anthesis. *a*, Anther; *s*, style; *l*, lodicule. Dehiscing anther below.

The perfect flower is hypogynous and simple in structure, consisting of a whorl of three stamens and a single carpel (Fig. 84).

One or more of the upper flowers of a spikelet are imperfect, the ovary being rudimentary and the anthers without pollen grains; frequently the terminal flower is missing altogether, and the flowering glumes and pales, though present, are poorly developed.

In many instances the entire spikelet is sterile; especially is this the case in the lowest three or four of an ear. Occasionally one or two of the apical spikelets are abortive also.

The stamens have slender filaments which are at first 2 to 3 mm. long, but grow rapidly when flowering occurs and reach a length of 7-10 mm.

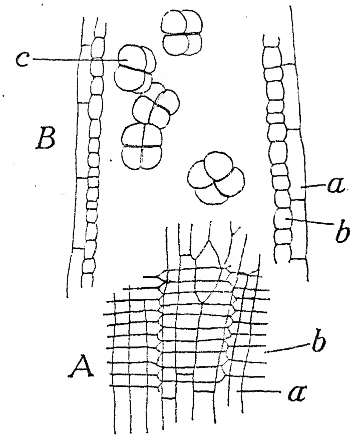


FIG. 85.—A, Surface view of anther (in chloral hydrate); B, longitudinal section of young anther; *a*, epidermis; *b*, endothecium; *c*, tetrad of pollen-grains (× 175).

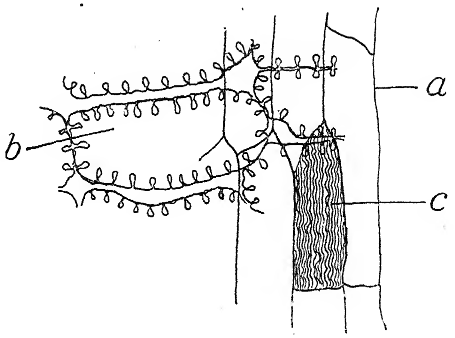


FIG. 86.—*a* and *c*, Epidermal cells of anther lobe; *b*, endothecial cell (× 250).

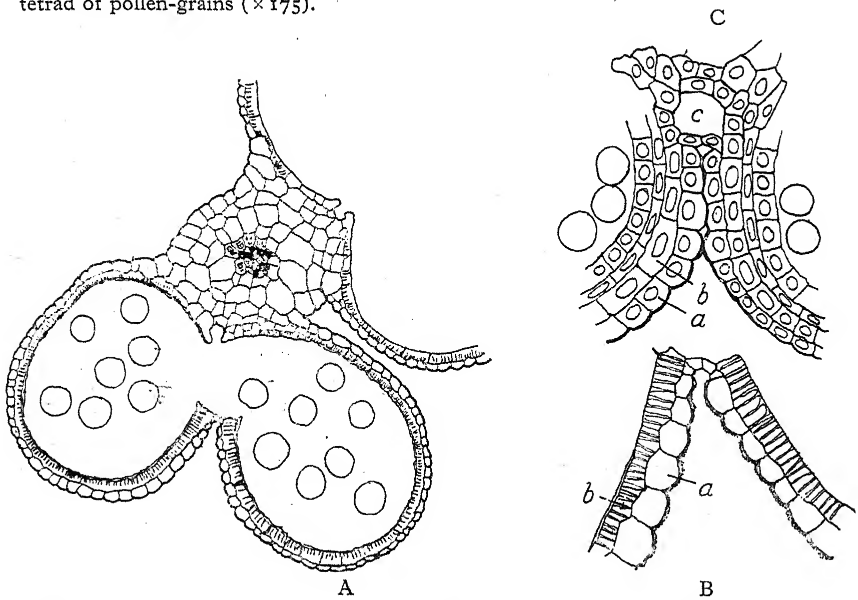


FIG. 87.—A, Transverse section of anther lobe just before dehiscence (× 63); B, enlarged view of cells at the point of dehiscence (× 125); C, earlier stage of point of dehiscence; *a*, epidermis; *b*, endothecium; *c*, schizogenous cavity.

The anthers are bi-lobed and versatile, the filament being attached to the connective at a point about 1 mm. from the base of the anther lobes.

They usually measure 3 to 4 mm. long and ·5 to 1 mm. across, and are green when young, becoming yellow or pink when ripe. Each lobe contains two loculi, the tissue between which breaks down at the time of dehiscence.

The filament of the stamen before anthesis is cylindrical, of uniform thickness, and from 100 to 120 μ in diameter. It consists of long parenchymatous cells ·5-·8 mm. long and 9-12 μ in diameter. In the centre is a small vascular strand possessing one or two annular tracheae 8-9 μ in diameter, with closely arranged rings or an occasional spiral thickening. When flowering occurs the filament grows rapidly, becoming very irregular in thickness, and the rings in its vessels greatly separated from each other.

The tissue of the connective is parenchymatous, with a slender vascular bundle resembling that of the filament running through it; in the epidermis investing it on the dorsal side are two rows of simple stomata.

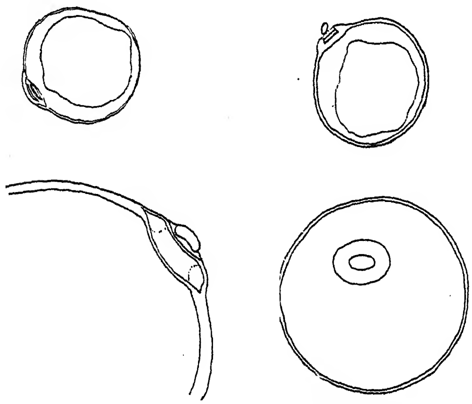


Fig. 88.—Pollen-grains showing pore in the exine.

The epidermis of the anther lobes is composed of narrow cells with their long axis parallel to the long axis of the anther. Each cell is from 50 to 80 μ long and 10 to 15 μ in diameter, its outer wall having a cuticle which is covered with fine wavy longitudinal lines (*c*, Fig. 86).

Immediately within is the endothecium (*b*, Figs. 85, 86, 87), consisting of narrow cells about 60 μ long and 10-12 μ broad with their long axes arranged across the cells of the epidermis: a short time before dehiscence of the anther the walls of these cells develop characteristic short pyriform thickenings, which project at right angles from the wall into the cell lumen (*b*, Fig. 86).

The pollen-grains are smooth and spherical, or slightly oval, somewhat irregular in size and form: their diameters measured in a dry state as shed from the anther are—

T. aegilopoides	37-45	*T. dicoccum*	48-52	*T. compactum*	52-61
T. monococcum	37-45	*T. durum*	48	*T. vulgare*	61-65
T. dicoccoides	44-64	*T. turgidum*	57-65	*T. Spelta*	65

In the exine is a circular or oval pore closed by a minute lid 4-5 μ in diameter (Fig. 88), which is pushed off when the pollen tube develops.

Within the pollen-grain are large numbers of minute oval starch-grains from 1 to 4 μ long; these are more abundant in the half of the grain

on which the pore is found and are utilised in the development of the pollen-tube ; they are not found in the immature pollen-grain.

The gynaecium consists of a single median carpel, with an obovate or obconical ovary, slightly trilobed in transverse section and flattened on the ventral side. At the time of anthesis it measures 1 mm. long and is about the same diameter across the upper portion.

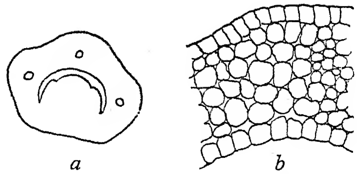


FIG. 89.—*a*, Transverse section of young ovary (×70) ; *b*, portion of its wall (×260).

Its sides are smooth, but the broad apex is clothed with numerous long finely-pointed unicellular hairs about 16 μ in diameter and varying in length from ·16 mm. to 1 mm.

The wall of the ovary averages ·35 mm. in thickness. It consists of delicate loosely-packed parenchyma 10-16 cells across, clothed on the outside with a well-defined epidermis, its inner surface being lined with a similar but thinner epidermal layer. Running longitudinally through it are two very fine lateral and one dorsal vascular strand, each of the former possessing three to six delicate tracheae, the latter usually only one (Fig. 89).

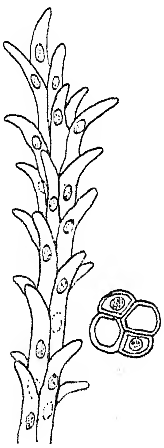


FIG. 90.—Upper part of stigmatic branch (×210) and transverse section of the same.

From the tip of the ovary arise two terminal styles 3-4 mm. long, which curve outwards when flowering occurs. Each has a central tapering column from which are given off 80-100 delicate stigmatic branches ·8 to 1·5 mm. long ; the latter extend to the base on the inner side, but only about one-third of the way down the outer side of each stylar column.

The two lateral vascular bundles of the ovary are continued some distance into the styles.

Each delicate stigmatic branch is composed of four rows of elongated cells about 250 μ long and 8-10 μ in diameter. They are joined throughout their whole length except at the upper end of each cell, which is free, and curved outwards into a bluntish point 24-30 μ long (Fig. 90).

The angles between the free ends of these cells and the sides of the branches form convenient resting-places for the pollen-grains shed from the dehiscent anther at the time of flowering.

Within the ovary is a single sessile anatropous ovule attached to a broad placenta on the inner ventral surface of the ovary (Fig. 91). It is about ·5 mm. long and ·4 mm. broad, and possesses two integuments ; the outer one, which is disintegrated before the seed is ripe, is shorter

than the inner one and does not reach the micropylar opening. Each of the ovular coats consists of a double layer of cells 14-16 μ thick.

The nucellus has a broad chalaza, and is composed of parenchyma surrounded by a well-defined epidermis of regular closely-fitting cells, which are almost square in transverse section and uniformly about 8 μ in diameter except where they abut on the micropyle, at which point the layer is thinner.

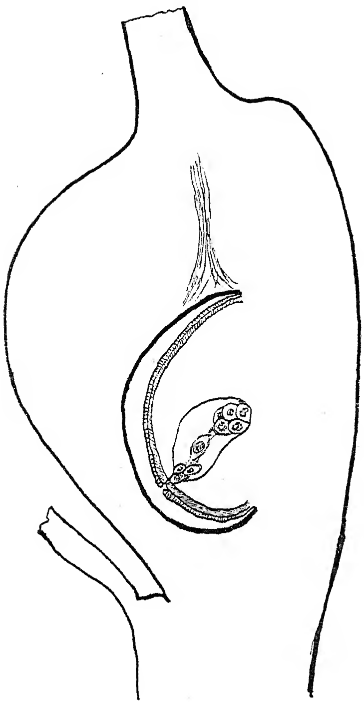


FIG. 91.—Longitudinal section of the ovary, and ovule with integuments and embryo-sac ($\times 50$).

Imbedded in it is the embryo-sac, ·27 mm. long by ·16 mm. broad, a large oval or pear-shaped cell whose narrow end is in immediate contact with the thin epidermis abutting on the micropyle; at other points it is surrounded by nucellar tissue usually 6 to 8 cells deep.

DEVELOPMENT OF THE SPIKELET AND FLOWER

In the early stages of the development of a spikelet of *T. vulgare* eight or nine flowers can be recognised, but under the ordinary conditions of plant growth in the field none of the spikelets yield this number of ripe grains. So soon as the three or four lowest flowers have reached a certain stage of development, the upper four or five cease to grow and their tissues become depleted of their cell-contents, the material probably going to assist in the nutrition of the rapidly growing flowers below.

In a very young spikelet all the cells of the tissues up to the apex contain normal cytoplasm and well-defined nuclei; but in the early part of June, when growth and differentiation of the parts of the flowers are proceeding rapidly, the cytoplasm and nuclei of the cells of the upper parts of the spikelet show signs of change. The cytoplasm loses its staining power and the nuclei begin to degenerate: later, the cytoplasm disappears, the nuclei remaining for a time, after which they also vanish, leaving only the cell walls.

Depletion of the cells begins first at the undifferentiated tip of the axis of the spikelet and gradually proceeds downwards to a point where the three or four basal flowers are growing normally.

The cell-contents of the periblem disappear before those of the plerome, and the stamens of the aborting flowers lose their contents and degenerate before the ovaries.

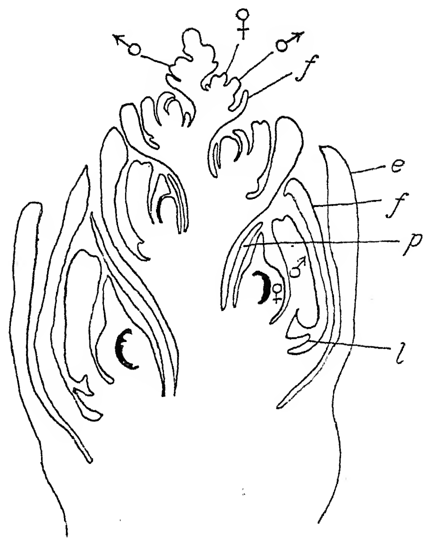
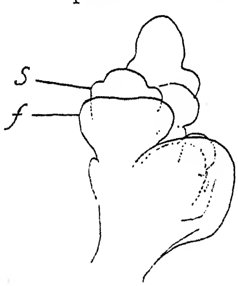


FIG. 92.—Median longitudinal section of a young spikelet (May 27). *e*, Empty glume; *f*, flowering glume; *p*, palea; *l*, lodicule; ♂, stamen; ♀, carpel (× 25).

The essential floral organs and the bracts by which they are enclosed arise in succession as bulging masses of meristem below the apex of the young flower (Figs. 92, 93).

The flowering glume arises first in the form of a thick semicircular zone surrounding the tip on the anterior side. Very soon the whorl of stamens can be recognised as three rounded papillae. A little later the carpel grows up as a crescent-shaped ridge closely encircling the hemispherical floral apex on the anterior side; about the same time the rudiments of the palea and the lodicules originate almost simultaneously, the latter from points on the axis slightly beneath the line of insertion of the stamens (Figs. 92, 93).



In a short time the rudiments of the styles are visible as two bluntish conical outgrowths of the apical margins of the young carpel. The upper part of the carpel grows over and closes round the apex of the axis, coming into contact

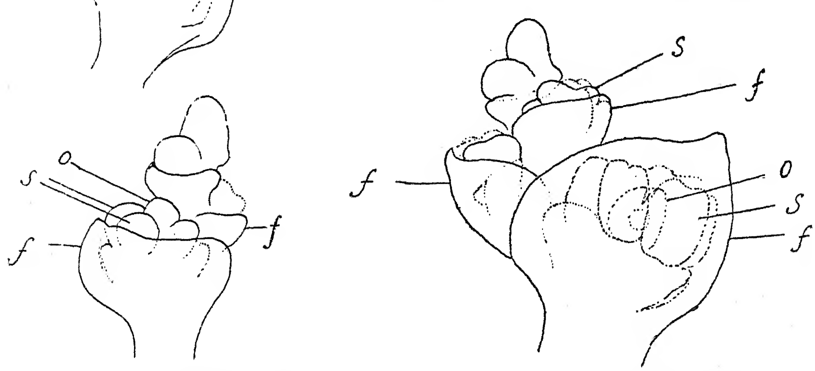


FIG. 93.—Upper flowers of a young spikelet showing developing flowers. *f*, Flowering glume; *s*, stamen; *o*, ovary (× 50).

with it and forming a chamber in which the enclosed portion of the axis

appears as a protuberance from the posterior inner surface of the cavity. The enclosed tip of the axis ultimately becomes the ovule (Figs. 94, 95).

The primordia of the stamens rapidly elongate, their transverse sections becoming oblong with rounded corners. At first they consist of homogeneous meristem, but differentiation into dermatogen, periblem,

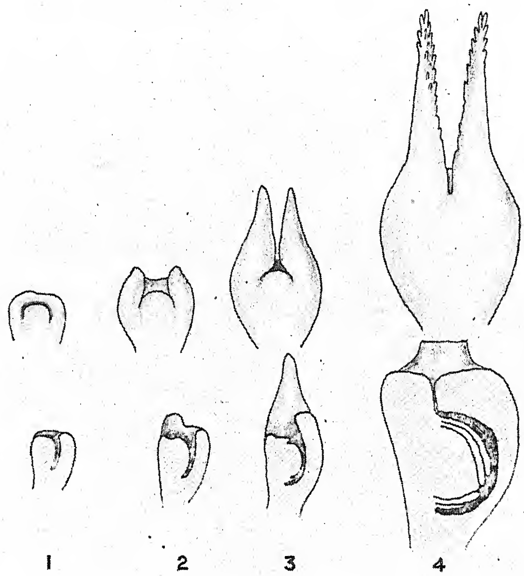


FIG. 94.—Stages in the development of the carpel (× 25).

and plerome with the initials of a central vascular strand is visible when the anther is about ·15 mm. in length.

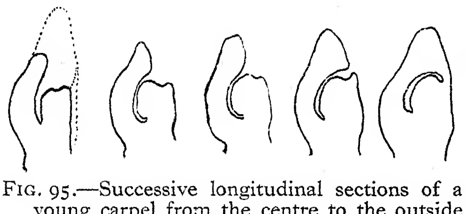


FIG. 95.—Successive longitudinal sections of a young carpel from the centre to the outside (× 25).

A single sub-epidermal archesporial cell is soon marked out in each corner of the anther. Each of these divides by periclinal walls into an outer primary parietal cell and an inner primary sporogenous cell. The former divides radially, and usually after two divisions the four cells produced form with the adjoining periblem cells the first parietal layer which encircles the sporogenous cell (Fig. 96). Two successive periclinal divisions follow, resulting in the production of three concentric parietal layers, the inner one in contact with the sporogenous cells becoming the tapetum, the next surrounding zone is the " middle " layer, the third,

immediately beneath the epidermis, developing into the endothecium of the mature anther.

For a time the sporogenous cells form a single longitudinal row. About the period when the tapetum is formed they divide both radially and longitudinally ; in a median longitudinal section two rows are seen at this stage, a transverse section usually showing six radially arranged cells, all of which on their outer surfaces are in contact with the tapetum ; these are transformed without further division into pollen mother-cells,

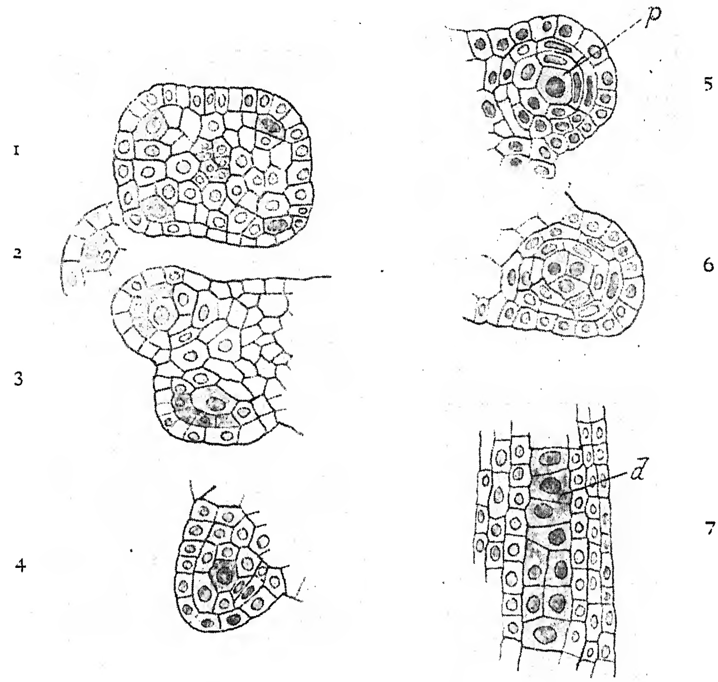


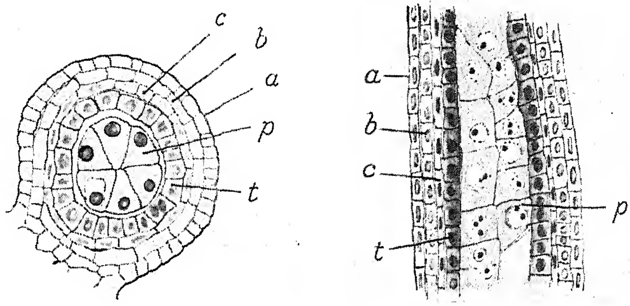
FIG. 96.—1, Transverse section of a young anther, showing initial archesporial cells at each corner; 2, first division of archesporial cell; 3-6, transverse sections of portions of an anther, showing subsequent divisions; 7, longitudinal section of 6; *p*, *d*, sporogenous cells (× 260).

which separate as the anther loculi enlarge, becoming free spherical or oval cells about 35 μ in diameter, each with a large central nucleus.

The free pollen mother-cells, which usually form a single layer lining the enlarged loculus (Fig. 98), undergo two successive divisions, the first being the reduction division, the daughter nuclei receiving in some races of wheats eight short chromosomes.

The number of chromosomes, however, is not the same for all races of wheat, and variations have been recorded in different cells of the same individual plant.

In the few cases in which I have been able to obtain reliable counts the haploid number is 8 in *T. monococcum*, and 16 the diploid number in some forms of *T. vulgare*. Larger numbers, not possible to count with certainty, I have observed in somatic cells of other forms of *T. vulgare*.



1 2

FIG. 97.—1, Transverse section, 2, longitudinal section of a loculus of a young anther (× 210); *a*, epidermis; *b*, endothecial layer; *c*, "middle" layer; *t*, tapetum; *p*, pollen mother-cells.

Overton (1893) gives 8 as the haploid and 16 as the diploid number in *T. vulgare*

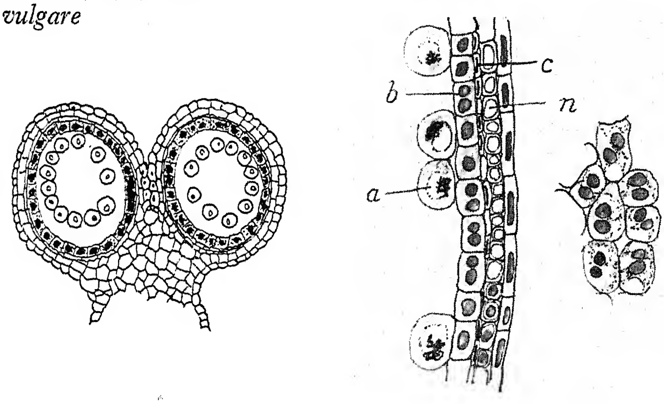


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FIG. 98.—1, Transverse section of anther-lobe, showing single ring of free pollen mother-cells in each loculus (× 100); 2, longitudinal section of a portion of the wall of the anther (× 260); 3, surface view of cells of the tapetum (× 260); *n*, endothecium; *c*, "middle" layer; *b*, tapetum; *a*, pollen mother-cells.

Körnicke (1896) found 16 in the somatic cells and 8 the reduced number in the embryo-sac and pollen mother-cells of *T. compactum*; in one vegetative cell of the anther of the same plant he counted 24 chromosomes.

The number observed by Dudley (1908) in the first division of the pollen mother-cells of *T. vulgare* was 8.

Spillman (1909) states that wheat has 40 or more chromosomes.

Nakao (1911) gives 8 as the haploid number, and Bally (1912) found the same in the wild *T. dicoccoides* and *T. vulgare*.

Sax (1918) found approximately 28 in the first division of the fertilised egg of *T. durum* (Kubanka) and approximately 40 in the fusion-nucleus of the embryo-sac.

Sakamura (1918), working chiefly with root-tips, obtained the following results :

	Diploid No.		Diploid No.		Diploid No.
T. vulgare	42	*T. turgidum*	28	*T. dicoccum*	28
T. compactum	42	*T. durum*	28	*T. monococcum*	14
T. Spelta	42	*T. polonicum*	28		

This series with 7 instead of 8 as the basic haploid number is remarkable. These numbers require further investigation.

At the first division the pollen mother-cell is bisected into two equal hemispherical halves with a cell wall between each ; the next division occurs in a plane at right angles to the first, and is also followed by the formation of a partition wall. The four pollen-grains thus produced lie in the same plane and remain for a short time within the delicate wall of the mother-cell ; later, each develops its own wall, which is differentiated when mature into an outer thick cutinised coat, the exine, and a thin cellulose lining, the intine of the spore ; in the exine is the pollen-tube pore previously described.

The pollen mother-cells when rounded off and the tetrads produced from them are arranged in regular order as a layer round the inner wall of the loculus ; the free pollen-grains become scattered irregularly throughout the cavity.

The pollen-grains germinate while still in the unopened anther, and before the protrusion of the pollen-tube producing the vegetative or tube-cell possessing an oval nucleus, measuring $7\,\mu \times 8\,\mu$, and two slender male gametes, each of which is curved and pointed at one end and measures $10\text{-}12\,\mu \times 2\,\mu$ (Fig. 103).

During the development of the pollen-grains changes occur in the cell layers constituting the walls of the anther loculi. The middle layer, which is the thinnest, collapses, its walls and scanty contents appearing as a narrow line round the outer boundary of the tapetum.

The tapetum consists of oblong parenchymatous cells square in transverse section with abundant cytoplasm and containing at first a single large nucleus. About the period when the sporogenous cells undergo their first division the nuclei of the tapetum divide, the two daughter nuclei in each cell persisting with no wall between them until the layer disappears, when the pollen-grains are perfectly developed (Fig. 98).

Golinski states that these double nuclei frequently coalesce to form a single nucleus again, but I have not been able to confirm this.

At the time of the divisions of the pollen mother-cells the tapetum shows signs of disorganisation, its cells separating more or less as the anther lengthens; later, it disappears altogether, its contents breaking down and furnishing nutritive material for the final development of the pollen-grains.

When the latter round themselves off and their coats become cutinised, the cells of the endothecium exhibit their characteristic thickenings and the exothecium or epidermis acquires its wavy-lined cuticle.

The ovule at first consists of a hemispherical mass of meristem within the carpellary cavity. Although it has the appearance of a lateral outgrowth on the inner posterior wall of the ovary, observation of its development suggests that it is derived from the morphological apex of the floral axis, its apparently lateral position being due to rapid growth of one side of the axis before the closure of the carpel.

In the earliest stages the nucellus is an almost uniform meristem, usually six or seven cells across. A cell immediately beneath the epidermis occupying the apex of the axial row of the mass grows into a large somewhat wedge-shaped archesporium. Division of the latter into two cells occurs with the formation of a periclinal wall between them; the dyad divides again similarly, and a tetrad row of megaspore mother-cells is produced, no parietal cell being cut off the archesporium at any stage (Fig. 99).

The outer three cells of the tetrad collapse rapidly and disintegrate, the innermost remaining for a short time imbedded in the nucellus some distance from the epidermis. Soon, however, the surviving mother-cell enlarges greatly, and pushing apart the cells on the sides of the narrow channel left by the disintegrated sister cells, ultimately comes into contact with the epidermis; later it functions as the embryo-sac.

The germination and development of the embryo-sac up to the eight-celled stage follow the usual course. It increases greatly in size and at the same time absorbs some of the adjacent nucellar tissue. At the micropylar end of the sac are two pear-shaped synergidae, each about 35-40 μ long and 16-20 μ broad. The ovum, a broader cell about 50 μ long and 32-35 μ across, is placed by the side of these; its nucleus is about 16 μ in diameter, and at the time of fertilisation generally contains two spherical nucleoli, one about 4 μ across, the other half this size. Near the ovum is the smaller upper polar nucleus, the lower one being placed near the three antipodals at the chalazal end of the megaspore.

The two polar nuclei move towards each other and meet at a point just behind the egg-apparatus (Fig. 100); here they remain in close contact for a considerable time, and probably fuse to form the primary endosperm nucleus just before the fertilisation of the ovum.

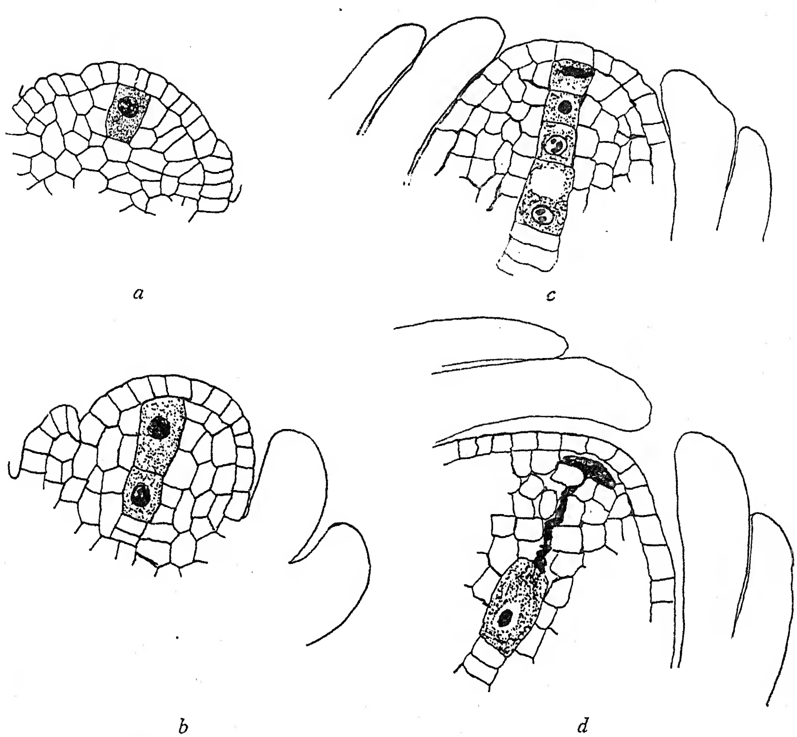


FIG. 99.—Median longitudinal sections of young ovules. *a*, Showing primary archesporial cell (×260); *b*, after its first division; *c*, tetrad stage; *d*, inner cell of tetrad after the collapse of the three outer cells. Outlines of the two ovular integuments are shown (*b*, *c*, *d* ×350).

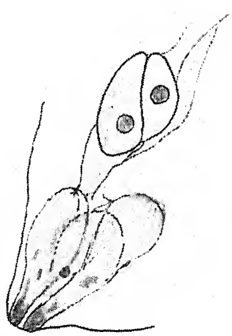


FIG. 100.—Egg apparatus and fusion-nuclei (June 12) (×350).

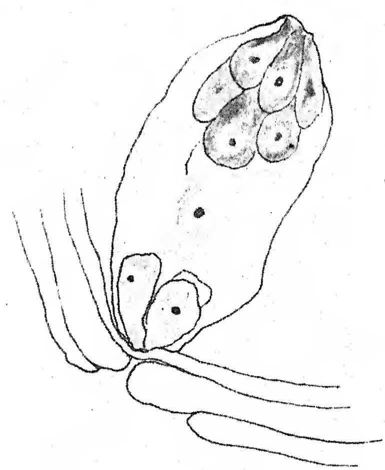


FIG. 101.—Embryo-sac before fertilisation (June 12) (×280).

The three antipodals divide and increase in size at the expense of the nucellus, producing a convex mass in contact with the wall of the embryo-sac on the placental side a short distance from the chalazal end (Figs. 101, 105). The antipodal complex in the mature sac usually consists of 6 to 10 large cells, although Körnicke mentions 36 or more. Each measures from 32 to 60 μ in diameter and contains much vacuolated cytoplasm and a large nucleus ; after fertilisation is accomplished the cells are gradually disorganised, their contents being apparently utilised in the formation of the endosperm ; their large nuclei, which may reach a diameter of 40 μ with nucleoli 16 μ or more across, are the last to disappear.

During the development of the flower, the stamens and their pollen-sacs are for a time considerably in advance of the carpel and ovule.

At the period when the anther possesses a well-defined single longitudinal row of sporogenous cells surrounded by two parietal and one epidermal zone, the carpellary cavity is open above, and the mass of meristem, from which the ovule is formed, shows neither integument nor archesporium.

When the first or inner integument is beginning to develop and the archesporium is clearly defined, the sporogenous cells of the anthers have divided and a double longitudinal row of closely fitting cells is seen in the pollen-sacs ; the tapetum has also been formed, so that at this stage there are four layers round the sporogenous cells.

The rudiment of the second or outer integument of the ovule appears before the archesporium divides. The nucellus becomes more and more enclosed by the integuments, and two successive mitoses of the archesporium occur, resulting in the production of a tetrad row of megaspore mother-cells. Pollen-grain tetrads, or rounded separate pollen-grains with single nuclei and more or less cutinised walls, are now found in the anthers ; the cells of the tapetum are still somewhat square in transverse section, but the cytoplasm is reduced and much vacuolated.

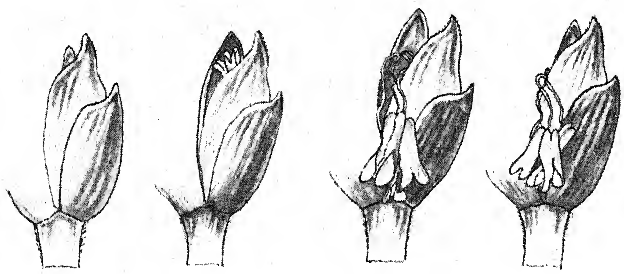
When the embryo-sac is ready for fertilisation, each pollen-grain contains the tube-nucleus and two gametes, the tapetum has become completely disorganised, and the endothecial layer shows its characteristically thickened walls.

Anthesis and Pollination

Anthesis, or opening of the flower, follows the escape of the ear from the upper leaf-sheath in five or six days, although in some instances it occurs on the first day, or may be delayed till the ninth after the appearance of the ear. The development of the stamens and gynaecium in the same flower proceeds at the same rate, and the pollen is ready to be shed from the anthers when the stigmas become receptive.

At the time of anthesis the thin-walled parenchyma of the lodicules becomes very turgid, the outer face of the tissue assuming a convex form. The two lodicules in this swollen state act as elastic cushions which push apart the flowering glume and palea, the separation taking place rapidly, often attaining a maximum in five minutes or less. Very slight mechanical stimulus either affects the turgidity of the lodicules or releases the edges of the glumes from each other, for the opening of the glumes often takes place rapidly, on gently running the ear through the hand, by touching the awns, or by the impact of the ears against each other as they are swayed to and fro in a breeze.

The angle of separation of the glumes varies considerably. In *T. aegilopoides*, *T. dicoccoides*, and *T. dicoccum*, and in some varieties of *T. vulgare*, it may reach 40° or more, especially in bright warm weather; in the majority of cases, however, it does not exceed 20°-30°, and in *T. Spelta*,



a *b* *c* *d*

FIG. 102.—Anthesis of lowest flower of a spikelet. *a*, 8.48 A.M.; *b*, 8.50 A.M.; *c*, 8.56 A.M.; *d*, 9.7 A.M., June 19, 1915 (×2).

T. compactum, and certain forms of *T. polonicum* and *T. vulgare* it is often less than this.

As soon as the glumes begin to separate, rapid changes occur in the floral organs. The styles, which at first lie close together and parallel to the long axes of the ovary, quickly curve away from each other, and the feathery stigmas spread out; in most wheats these remain within the glumes, but in some varieties their tips may be seen projecting on opposite sides of the flowering glume. At the same time the filaments of the stamens lengthen rapidly, expanding from a length of 2 or 3 mm. to 7-10 mm. in two to four minutes, and the anthers are thrust out of the opening between the glumes, usually on the outer face of the spikelet (Fig. 102).

The pollen-sacs commence to dehisce when the filaments begin to lengthen and a variable amount of pollen is left in each flower; self-pollination is the rule.

Dehiscence progresses from the tip to the base of the anther, and is

completed after the latter is pushed out of the flower, a large proportion of the pollen being shed into the air. In many flowers all the anthers are carried into the open air at the time of anthesis, but quite frequently one or more fail to escape from the glumes, being entrapped behind the folded margin of the palea or caught between the tips of the closing glumes. Retention of the anthers, which is most frequent in dense-eared wheats, occurs chiefly in the lower spikelets of ears and the smaller flowers of each spikelet, some of which do not open at all. Of flowers which open, the glumes generally remain widely separated from 5 to 15 minutes and then slowly close again, the lodicules meanwhile becoming flaccid; the time taken in opening and closing completely varies from 8 to 30 minutes or more, the average being about 20 minutes.

Anthesis occurs in the early part of June at Reading, the individual flowers opening at various times of the day, from dawn till an hour or two after sunset.

Observations upon representatives of the chief kinds of wheat revealed no characteristic specific differences; flowering was observed to occur during most hours of daylight, but it was especially frequent between the hours of 5-7 A.M., 9-10 A.M., 2-3 P.M., and 8-9 P.M. Meteorological conditions appear to influence the time at which it takes place. Gitkova at Saratoff, Russia, found the flowering of a variety of *T. vulgare* and *T. durum* was most intense between 5 and 7 A.M., with a second maximum between 5 and 6 P.M. Leighty and Hutcheson also noted two periods of extensive blooming during daylight, namely, from 7 to 9 A.M., and in the middle of the afternoon, with a secondary morning period about 11 A.M.

The basal flower is the first to open in each spikelet, the others following in regular succession upwards.

The position of the first spikelet to flower varies a little; it is generally in the middle third of the ear, and usually near the upper part of this section, except in the case of *T. aegilopoides*, *T. monococcum*, and *T. dicoccoides*, in which the spikelets to open first are nearer the tip, at a point about the middle of the upper half.

In ears possessing 16-18 spikelets the 8th to the 12th usually open first; in those with 28-30, the 16th to 20th. Anthesis proceeds upwards and downwards from these points in more or less regular succession, the apical and basal spikelets being the last to flower. Sometimes 4 or 5 spikelets on one side open before the rest; in other cases adjacent spikelets on opposite sides of the rachis flower almost simultaneously.

The successive flowers of a spikelet usually open on successive days, but occasionally two of the same spikelet open on the same day, one in the morning, the other later, after an interval of 5 or 6 hours.

At Reading the whole ear often completes its flowering in 3 to 5

Time of Anthesis of an Ear of "Swan" Wheat (Dense-eared Form of *T. vulgare*)
June 28-July 5, 1916—somewhat dull weather

Left Side.						Right Side.					
No. of Spikelet.	Flowers of Spikelet.					Flowers of Spikelet.					No. of Spikelet.
	5th.	4th.	3rd.	2nd.	1st.	1st.	2nd.	3rd.	4th.	5th.	
23	..	..	..	July 1 9 A.M.	June 29 noon	June 30 9.30 A.M.	July 1 7 A.M.	July 3 10.30 A.M.	..	..	22
21	..	July 2 4 P.M.	June 30 11 A.M.	June 29 11.15 A.M.	June 28 noon	June 28 11-12 A.M.	June 29 11 A.M.	June 30 10 A.M.	..	..	20
19	..	July 2 5-6 A.M.	June 30 10 A.M.	June 29 10.30 A.M.	June 28 11-12 A.M.	June 28 11-12 A.M.	June 29 7.30 A.M.	June 30 9.30 A.M.	July 1 9.50 A.M.	..	18
17	..	July 3 9-10.30 A.M.	July 1 11.30 A.M.	June 30 10 A.M.	June 29 5-6 A.M.	June 28 11-12 A.M.	?	?	?	..	16
15	..	..	July 2 5-6 P.M.	June 30 9.30 A.M.	June 28 6.30 A.M.	June 28 7.45 A.M.	June 28 1-2 P.M.	June 30 9.30 A.M.	July 2 5-6 P.M.	..	14
13	July 2 4 P.M.	July 1 9.50 A.M.	June 30 9.30 A.M.	June 29 6.15 A.M.	June 28 9-12 A.M.	June 28 9-12 A.M.	June 28 3.30 P.M.	June 30 9.30 A.M.	July 1 9.50 A.M.	July 2 2-3 P.M.	12
11	July 4 9-10 A.M.	July 3 9-10 A.M.	June 30 10 A.M.	June 28 3.30 P.M.	June 28 9-12 A.M.	June 28 9-12 A.M.	June 29 noon	..	..	..	10
9	..	July 4 4.45-5.15 P.M.	July 3 9-10.30 A.M.	*	June 30 7.50 A.M.	June 30 9.30 A.M.	July 1 5.30-6 A.M.	July 2 10-10.30 A.M.	July 3 9-10 A.M.	..	8
7	*	*	*	July 1 9.50 A.M.	June 30 10 A.M.	June 30 noon	July 1 10-11 A.M.	July 2 3-3.30 P.M.	July 3 ?	July 4 7 P.M.	6
5	..	*	July 4 5-6 P.M.	*	July 1 10-11 A.M.	July 1 9.50 A.M.	July 2 10-10.30 A.M.	July 4 9-11 A.M.	*	*	4
3	..	*	*	July 5 11 A.M.-1 P.M.	July 1 10-11 A.M.	July 2 2.50 P.M.	July 3 ?	July 5 6-6.30 A.M.	*	..	2
1 (base)	..	..	*	*	*						

* These flowers opened imperfectly or not at all, although many of them produced grain.

Anthesis on Successive Days

	No. of Spikelets (counting from Base of Ear).																							No. of Flowers opening on the Same Day.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	
June 28 .	..	..	..	..	..	..	..	..	..	1	2	2	1	2	1	1	..	1	1	1	1	..	..	14
,, 29 .	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	1	1	1	1	1	..	1	8
,, 30 .	..	..	..	..	..	1	1	1	1	..	1	1	1	1	1	..	1	1	1	1	1	1	..	15
July 1 .	..	..	1	1	1	1	1	1	..	..	..	1	1	..	..	..	1	1	..	..	..	1	1	12
,, 2 .	..	..	..	1	..	1	..	1	..	..	..	1	1	1	1	..	..	..	1	..	1	..	..	9
,, 3 .	..	1	..	..	..	1	..	1	1	1	1	..	..	..	..	..	1	..	..	..	..	1	..	8
,, 4 .	..	..	..	1	1	1	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	5
,, 5 .	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2

Time of Anthesis of an Ear of *T. Spelta* (June 24-26, 1916—somewhat dull weather)

Left Side.				Right Side.			
No. of Spikelet.	Flowers of Spikelet.			Flowers of Spikelet.			No. of Spikelet.
	3rd.	2nd.	1st.	1st.	2nd.	3rd.	
21	..	..	June 25 11.40 A.M.	June 25 11 A.M.	..	..	20
19	..	June 26 3.30 P.M.	June 25 9.30-10.10 A.M.	June 25 ?	June 26 ?	..	18
17	..	June 26 7-8 A.M.	June 25 6-7 A.M.	June 25 10.16 A.M.	*	..	16
15	..	June 25 9.30-10.10 A.M.	June 24 6-7 A.M.	June 24 6-7 A.M.	June 25 6-7 A.M.	..	14
13	..	June 25 10-12 A.M.	June 24 6-7 A.M.	June 24 6-7 A.M.	*	..	12
11	..	*	June 25 11 A.M.	June 24 7.30 A.M.	June 25 10.40 A.M.	..	10
9	..	June 25 11.40 A.M.	June 25 6-7 A.M.	June 25 6-7 A.M.	June 25 3.30 P.M.	..	8
7	..	*	June 26 7-8 A.M.	June 25 10.30 A.M.	June 26 7.45 A.M.	..	6
5	..	June 26 7.45 A.M.	June 26 7-8 A.M.	June 26 7.45 A.M.	..	..	4
3	..	..	..	..	..	..	2
1	..	..	..				

* These flowers did not open ; the three lowest spikelets were barren.

One or two anthers remained within the glumes of the majority of the flowers.

Anthesis on Successive Days

	No. of Spikelet (counting from Base of Ear).																					No. of Flowers opening on the Same Day.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
June 24 . .	..	..	..	..	..	..	..	..	..	1	..	1	1	1	1	..	..	..	..	..	..	5
„ 25 . .	..	..	..	..	..	1	..	2	2	1	1	..	1	1	1	1	1	1	1	1	1	16
„ 26 . .	..	..	..	1	2	1	1	..	..	..	..	..	..	..	..	..	1	1	1	..	..	8

days when the air is warm and the sky clear: in wet or dull weather the period is prolonged to 6 or 8 days.

The first ear to flower belongs to the primary culm and is followed by those on the lateral stems in order of origin, the whole plant finishing the process in normal seasons in about 8 days.

	No. of Spikelets of the Ear.	Spikelets which open first, counting from the Base upwards.	Days occupied in completing Anthesis of an Ear.
T. monococcum	28	17th-19th	. .
T. dicoccoides	15	10th-13th	6
T. dicoccum—			
"Ajar"	19	12th-15th	3-5
Indian	17	8th-12th	4
European	30	18th-20th	. .
T. Spelta	21	13th-15th	3-5
T. vulgare—			
Chinese	20	10th-12th	4
Sq. head	24	12th-14th	6-8
Lammas	18	10th-12th	5
Karachi	16	7th-9th	4
T. durum	25	12th-14th	4
T. turgidum	27	18th-20th	. .
T. compactum	17	7th-9th	5

The following results were obtained by Obermayer:

NUMBER OF FLOWERS OPENING EACH DAY ON FIVE ORDINARY HUNGARIAN WHEAT PLANTS

1912.	Up to 7 A.M.	7-9 A.M.	9-11 A.M.	11 A.M.-1 P.M.	1-3 P.M.	3-5 P.M.	5-7 P.M.	After 7 P.M.	Total.
June 5	. .	. .	9	10	3	6	28	. .	56
,, 6	14	17	25	34	10	28	37	3	168
,, 7	39	64	27	65	43	33	51	6	328
,, 8	113	72	98	41	30	58	35	6	453
,, 9	112	49	57	29	31	45	25	6	354
,, 10	75	50	89	13	17	26	. .	. .	270
,, 11	24	48	11	4	12	21	18	. .	138
,, 12	8	66	27	17	7	9	17	6	157
,, 13	15	9	32	8	6	7	7	. .	84
,, 14	. .	9	2	. .	. .	. .	7	. .	18
,, 15	. .	3	2	. .	. .	. .	. .	. .	5
Total .	400	387	379	221	159	233	225	27	2031

Flowering began before 5 A.M. and continued throughout the day, a very small number opening after 7 P.M. The period of most intense flowering was before 11 A.M., the fewest flowers opening between 1 and 3 P.M.

He found a maximum of 23 flowers of an ear opening on one day, and observed that the flowering of single ears of an ordinary Hungarian wheat was completed in 4 or 5 days, the greatest number of flowers opening on the third or fourth day.

Although self-pollination usually occurs just before or at the time of anthesis, cross-pollination is possible, since the glumes remain separated and the flower exposed for 15 to 20 minutes and liable to the introduction of foreign pollen either by the agency of the wind or through transference by small insects, especially thrips, which are frequently found in the flowers.

More than 1500 kinds of wheat have been grown annually at Reading during several years, and although self-fertilisation is found to be the rule, five or six natural hybrids are met with nearly every year. These are most frequent among wild *T. dicoccoides* and some forms of *T. vulgare*, but I have observed them occasionally in *T. turgidum*, *T. durum*, *T. polonicum*, and *T. Spelta*. I have never seen a case of natural crossing in *T. monococcum* or *T. dicoccum*.

Flowers from which the anthers have been removed before maturity frequently produce grain when left unprotected. Salmon in S. Dakota found that over 76 per cent of emasculated flowers left without cover in the field produced grain, but he obtained no grain from a similarly emasculated ear enclosed in a paper bag.

Obermayer emasculated 29 flowers of an ear of Squarehead wheat and removed all the rest from the ear. Twenty of the emasculated flowers produced grain; 15 out of 25 flowers of an ear of Hungarian wheat similarly treated " set " grain and 28 out of 34 of an American variety.

Leighty and Hutcheson also obtained 507 grains from 1240 emasculated and unprotected flowers (about 41 per cent) of 70 ears of wheat, and only two grains from 388 similarly treated flowers (about ·5 per cent) covered with paper bags. In another series of experiments they observed the production of grain by more than 83 per cent of the emasculated and uncovered flowers, and less than 1 per cent in the case of emasculated flowers enclosed in paraffined paper bags.

Fertilisation and Development of the Grain

I have not succeeded in inducing the development of the pollen-tube artificially, away from the flower, but in $1\frac{1}{2}$ to 2 hours after normal pollination the pollen-tube appears, its tip turns towards the style and pushes its way between the cells into the intercellular space in the centre of the style, along which it grows rapidly downwards towards the ovule. In the cases I have examined I found that the two curved male gametes travel into the pollen-tube before the oval tube nucleus (Fig. 103), and very frequently the latter never leaves the pollen grain.

The tube, on reaching the cavity of the ovary, finds its way to the micropyle of the ovule, through which it passes, and finally comes into contact with the egg apparatus. About the time of fertilisation the

synergidae degenerate, some residual debris from them remaining near the ovum for a short period.

The fusion of one of the male gametes with the ovum was observed in examples collected between 30 and 40 hours after pollination: the fate of the second gamete I have not been able to discover with certainty. The two polar nuclei of the embryo-sac remain in contact without fusing, up to near the time of fertilisation. If they fuse and unite with the second male gamete they do so very rapidly, since free nuclei resulting from the division of the primary endosperm nucleus are found a few hours after the union of the male gamete with the ovum, and before the former has lost its individuality (Fig. 104).

Sax observed the union of the second male gamete with the fusion-nucleus in "Kubanka" wheat (*T. durum*), but appearances in some cases suggest that the double fertilisation process does not always take place, at any rate in some forms of *T. vulgare*.

(i.) *Endosperm*.—After fertilisation the ovum shows little sign of

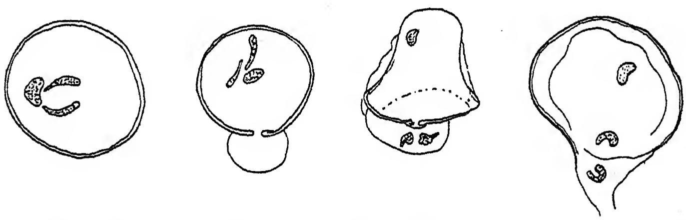


Fig. 103.—Germination of pollen-grains, taken from the stigmas of a flower, showing the transference of the gametes into the pollen-tube (×350).

change for a few hours. The primary endosperm nucleus, however, begins a rapid division immediately; free nuclei containing 3-5 well-defined nucleoli appear in the embryo-sac in considerable numbers, even before the male gamete is lost in the ovum (Fig. 104); these become scattered irregularly in the thin cytoplasmic lining of the embryo-sac, and are more numerous in the neighbourhood of the embryo. By the time the embryo is 10-15 celled, 8-10 days after pollination, a single continuous layer of cells lines the embryo-sac, and endosperm cells with dense non-vacuolated cytoplasm fill up the narrow pocket-like cavity in which the embryo lies, walls between the cells appearing first in this region.

Six or seven days later the large vacuole of the sac is almost or entirely filled with endosperm tissue which develops centripetally, the peripheral cells being smaller than those nearer the centre.

The aleuron layer is not clearly marked out from the rest of the endosperm until the grain has attained about half its final size.

(ii.) *Nucellus*.—While the embryo is developing within the embryo-sac the surrounding nucellar tissue, which at first is several cells thick,

becomes gradually disorganised and absorbed, its disappearance being most rapid in the region of the embryo and on the dorsal side of the ovule.

The epidermis of the nucellus, however, continues for a long time as a living tissue, its cells dividing and expanding as the ovule grows; the position, size, and regular arrangement of the cells render it extremely liable to be mistaken for the aleuron layer before the latter is distinctly differentiated from the amyliferous cells of the endosperm. Later, its cell-contents become disorganised, the remains of the cytoplasm tending

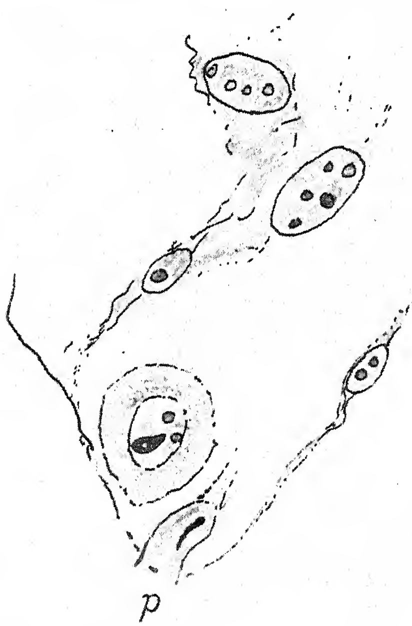


FIG. 104.—Section of the micropylar portion of the embryo-sac, showing the ovum with a male gamete within it, four endosperm cells and *p*, tip of the pollen-tube with the second male gamete (× 420).

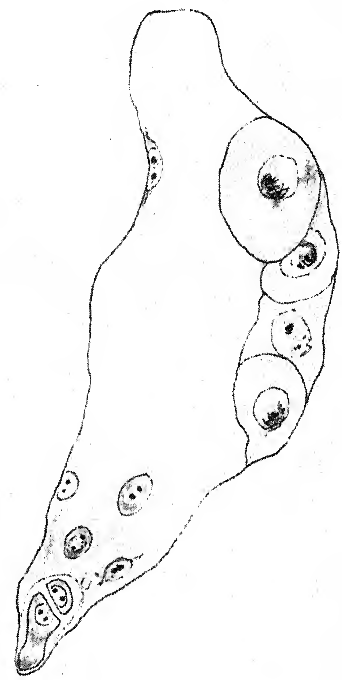


FIG. 105.—Longitudinal section of the embryo-sac (June 16) showing 2-celled embryo, endosperm cells and the large antipodals (× 84).

to collect as a thin layer across the middle of the cell, where it is easily mistaken for a cell wall dividing the epidermis into a double-celled layer. Ultimately the radial walls of the nucellar epidermis are more or less absorbed, and when the grain shrinks through the loss of water during the ripening process the single-celled tissue collapses and its upper and lower walls are crushed together, finally appearing in the ripe grain as a highly attenuated layer, recognisable only with difficulty as a delicate covering on the outer surface of the aleuron cells.

(iii.) *Antipodal Cells.*—As the growth of the embryo and endosperm proceeds the antipodal cells slowly degenerate, the cytoplasm disappearing first, debris of the large nuclei being visible for some time after the cells have been stretched and flattened by the growth of the surrounding parts of the ovule.

(iv.) *Filling of the Endosperm Tissue.*—The storage of the endosperm with reserves begins when the tissue is completely formed, *i.e.* 10-14 days after fertilisation, and continues for five or six weeks, till the grain is ripe.

The course of events in regard to the deposition of starch is readily followed. The soluble carbohydrate from which it is formed is manufactured in the stems and leaves of the plant and sent along the conducting strand which enters the base of the ovary, and traverses the raphe on the furrow side of the anatropous ovule to the morphological base of the latter in the upper part of the ovary ; from this point it diffuses into the endosperm, and it is in this region away from the embryo that starch grains are first observed in the centre of the two " cheeks," right and left of the furrow of the ovary.

When the endosperm tissue has almost or quite completely filled the cavity of the embryo-sac, minute starch grains are first seen near the nuclei of the cells ; later, they are produced at many points in the cytoplasm and increase rapidly in number and size, growing into thin lenticular structures which for a time are all similar in diameter.

Not all the reserve cells are filled with starch at the same time nor at the same rate. About three weeks after fertilisation those in the upper part of the ovule are crowded with fully-formed grains ; half-way down and along the furrow to near the base they are only partially filled with smaller grains, while the cells in closer proximity to the embryo contain but a few minute grains or none at all. In five or six weeks all the cells of the endosperm contain starch, except those of the aleuron layer, and a few layers in contact with the back of the scutellum ; ultimately, the majority become densely packed throughout with starch grains of various sizes, those formed in the later period of ripening remaining small.

The greatest amount and the largest grains are formed in the large cells in the centre of the " cheeks " of the grain, the peripheral region of the endosperm containing a small proportion of starch and a large number of small grains.

The deposition of starch progresses from the upper part of the grain towards the embryo in a diagonal plane, roughly parallel to the back of the scutellum.

The part of the grain stored last lies round the upper margin of the scutellum on the dorsal side, a region which is frequently opaque and mealy in ripe grains, in which the rest of the endosperm is translucent and flinty.

The slow, late deposition of the starch on the dorsal side and near the embryo appears to be due to the difficulty of diffusion from the conducting strand across the starch-laden cells near the furrow, and to the fact that the developing embryo for a time uses for its growth some of the soluble carbohydrates which would otherwise be converted into starch grains.

Immediately behind the scutellum a layer 3-5 cells in thickness becomes filled with starch, and when the final ripening occurs it shrinks and forms a thin band of crushed cells (Figs. 10, 11).

Concomitant with the deposition of starch in the endosperm the cytoplasm and nuclei of the cells undergo considerable change. In the earliest stages the cytoplasm fills the cells ; as the latter grow and expand it forms a lining inside the cell walls and surrounds the large central vacuoles ; the oval nuclei lie close to the walls, and there are no visible reserves in the cells. Later, starch grains are formed in enormous numbers as already described, and are packed closely in the cell-cavities.

In practically all the endosperm cells in which starch is accumulated the protoplasmic contents die and become more or less disorganised. The nuclei lose their nucleoli and clear outline and show other signs of degeneration even before the cells are crowded with starch grains. Sooner or later they become squeezed into the spaces between the densely packed grains, and when stained appear in optical section as irregular stellate or reticulate structures, coarse at first when the interstices are comparatively wide, but in the dessication which occurs during ripening the starch grains are forced closer together and the nuclear star or reticulum then appears composed of thin rays of tangled strands.

In the parts previously mentioned as the last in which starch is accumulated the nuclei are not so severely crowded, and some of them may retain their round or oval form even up to the time of ripening of the grain ; few, however, escape the crushing described.

The rest of the protoplasmic contents of the cells is similarly forced into the spaces between the starch grains, the latter then appearing to be imbedded in a matrix of protein.

(v.) *The Development of the Embryo.*—After a rest of a few hours the fertilised ovum divides into two cells by a transverse wall, the large basal suspensor cell apparently undergoing little or no further division. Brenchley states that the first division takes place about five days after pollination ; it is doubtless influenced by atmospheric temperature and other factors, for I find that it frequently occurs about forty to fifty hours after pollination. The upper cell, from which the embryo develops, divides by a wall parallel to the first, and then by a wall at right angles through both the cells produced, giving rise to a five-celled embryo (Fig. 106).

By further division in all directions the latter rapidly increases in size,

and in a few days a central core of cells with a surrounding dermatogen layer is recognised (4, Fig. 106).

Soon the embryo becomes a club-shaped mass of cells with a narrow elongated base, and after reaching a length of ·3-·4 mm. the first sign of differentiation is visible; a lateral notch or depression within which the growing-point is situated (*a*, Fig. 106) appears on the side of the embryo opposite to the endosperm.

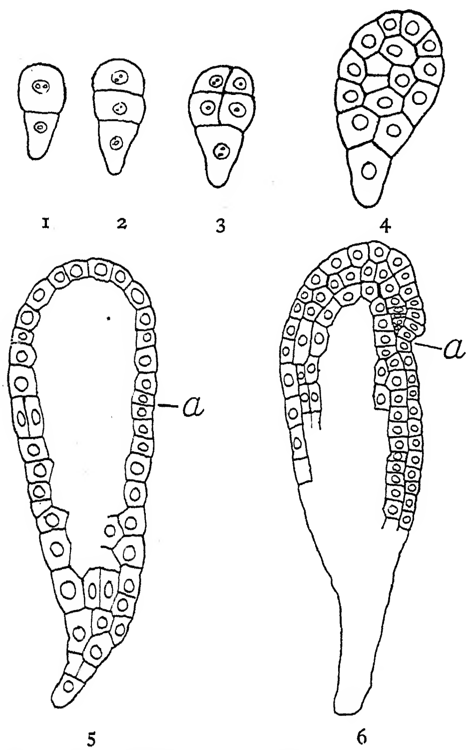


FIG. 106.—Longitudinal sections of young embryos. *a*, Growing-point; 1-5 (× 210); 6, (× 130).

From the distal portion of the embryo above the notch the scutellum arises; this is a terminal structure, which I consider the cotyledon.

By the time the embryo has reached a length of about ·5 mm. the coleoptile appears in the form of a ring surrounding the stem apex, the upper half of the ring developing more rapidly than the lower part, and appearing in longitudinal section as a curved scale covering the growing-point. Later, when the embryo is about 1 mm. long, the rudimentary first foliage leaf arises, the plumule consisting at this stage of (1) the short and somewhat cone-shaped coleoptile with a circular terminal opening, (2) the rudimentary foliage leaf alternating with the coleoptile, and (3) the stem apex within.

Growth of the epiblast now begins.

After this stage rapid intercalary growth commences at the base of the scutellum near the point of origin of the coleoptile. The upper part of the scutellum which I regard as the blade of the cotyledon is lifted away from the plumule, thus allowing for the subsequent unhindered growth of the latter.

The rapidly lengthening portion represents the sheath of the scutellum, the whole development being similar to that of the foliage leaves of grasses generally.

At first the sheath of the scutellum is thin; later it becomes thicker,

and a short overhanging protuberance arises at the end of the scutellum blade (*v*, Figs. 10, 107); this structure, which is sometimes termed the "cotyledonary" sheath, I regard as the ligule of the scutellum.

The epithelial layer of the scutellum does not begin to assume its final form until the extension of the scutellum sheath is completed.

Differentiation of the primary root commences when the embryo is about ·5 mm. long.

Before the embryo is 1 mm. long the plerome, periblem, and root-cap

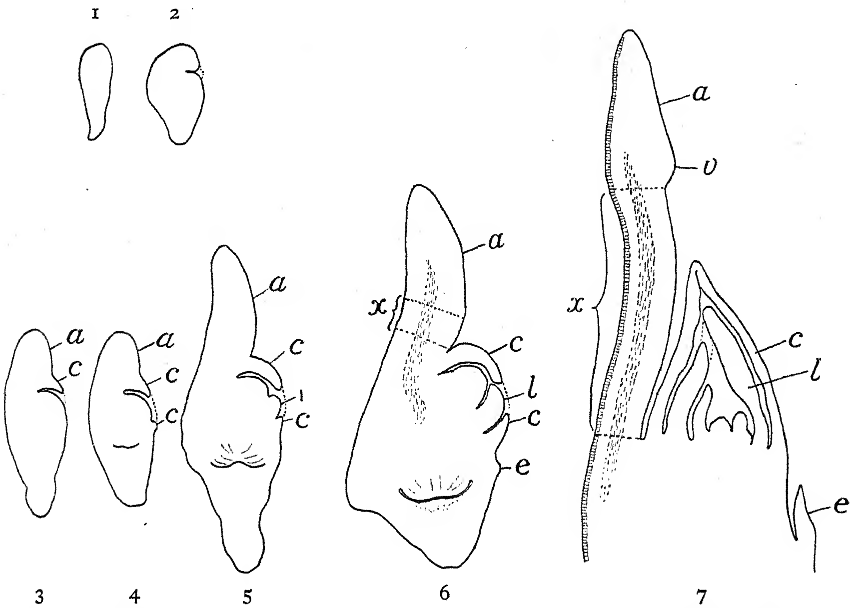


FIG. 107.—Longitudinal section of embryos in different stages of development (× 50). *a*, Upper portion of the scutellum (blade of the cotyledon); *x*, intercalary zone of scutellum (sheath of the cotyledon); *v*, "ventral" scale (ligule of the cotyledon); *c*, coleoptile; *l*, first foliage leaf; *e*, epiblast.

Length of embryos, 1, ·25 mm.; 2, ·25 mm.; 3 and 4, about ·5 mm.; 5, ·9 mm.; 6, 1·1 mm.; 7, 2 mm.

are clearly marked out and can be traced back to two or three initial cells, situated in the centre of the undifferentiated mass of tissue which forms the lower half of the embryo (Fig. 108). At this stage the coleoptile and the rudiments of the first foliage leaf are visible round the stem apex.

Through division of the meristem at the root-tip the length of the root increases and the tissue of the periblem and plerome is augmented at a different rate from that of the root-cap and the surrounding ground tissue, with the result that the adjacent cell walls in this region are torn asunder and a schizogenous cavity is formed round the tip of the root (Fig. 108).

By further growth in length of the root the cavity is extended and

ultimately appears in the completely formed embryo of the grain as a cylindrical space surrounding the root (Fig. 10), the ground tissue of the lower part of the embryo, within which the root has developed, now constituting the coleorhiza or root-sheath.

(vi.) *Integuments and Pericarp.*—During the growth of the ovule and seed the two integuments undergo considerable change. The outer coat, like its inner companion, at first consists of two cell-layers (*c*, *d*, Fig. 109).

About the time when the fertilised ovum commences its division it begins to degenerate; its cells lose their turgidity, the cytoplasm disappears, and the elongated nuclei become thinner. Later, the

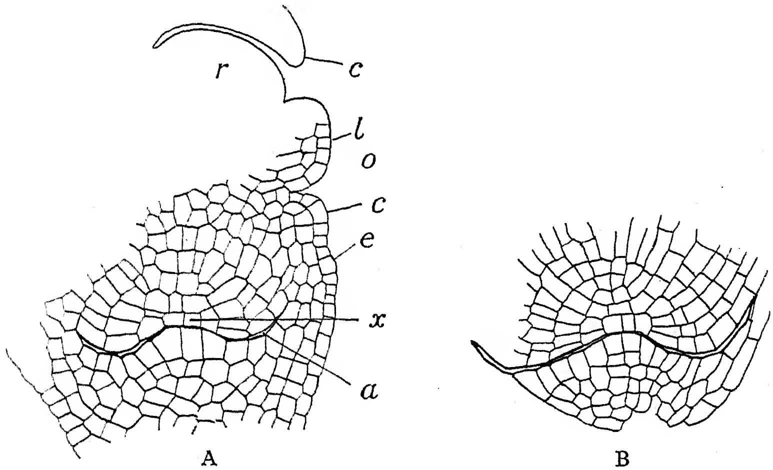


Fig. 108.—A, Longitudinal section of young embryo (× 175); *c*, coleoptile; *l*, first foliage leaf; *e*, epiblast; *r*, stem apex; *x*, initial cells of the periblem of the root; *a*, schizogenous cavity; B, longitudinal section of the root and root-cap region of the embryo; slightly later stage than A (× 140).

cell-contents disappear entirely, the delicate walls shrivel, and are finally disorganised altogether.

The inner integument, however, remains, and retains its vitality until the grain has reached the maximum size. The cells of its two layers up to this stage of development remain quite distinct and increase in length with the growth of the seed, the long axes of the cells of the separate layers crossing each other at an acute angle.

A short time before the milk-ripe stage (p. 140) the cell-contents of the outer layer gradually disappear, a semi-permeable cuticle is developed on the outer surface of the layer and the cells collapse (3, *c*, Fig. 109). The cell-cavities of the inner layer are recognisable for some time longer, and within them, in yellow and red-grained wheats, is formed a yellow or reddish-brown oily or resinous substance, which is partially absorbed by

the cell walls, and, being visible through the more or less translucent pericarp, gives the grain its characteristic tint.

Ultimately, the radial walls of this inner layer are disorganised or

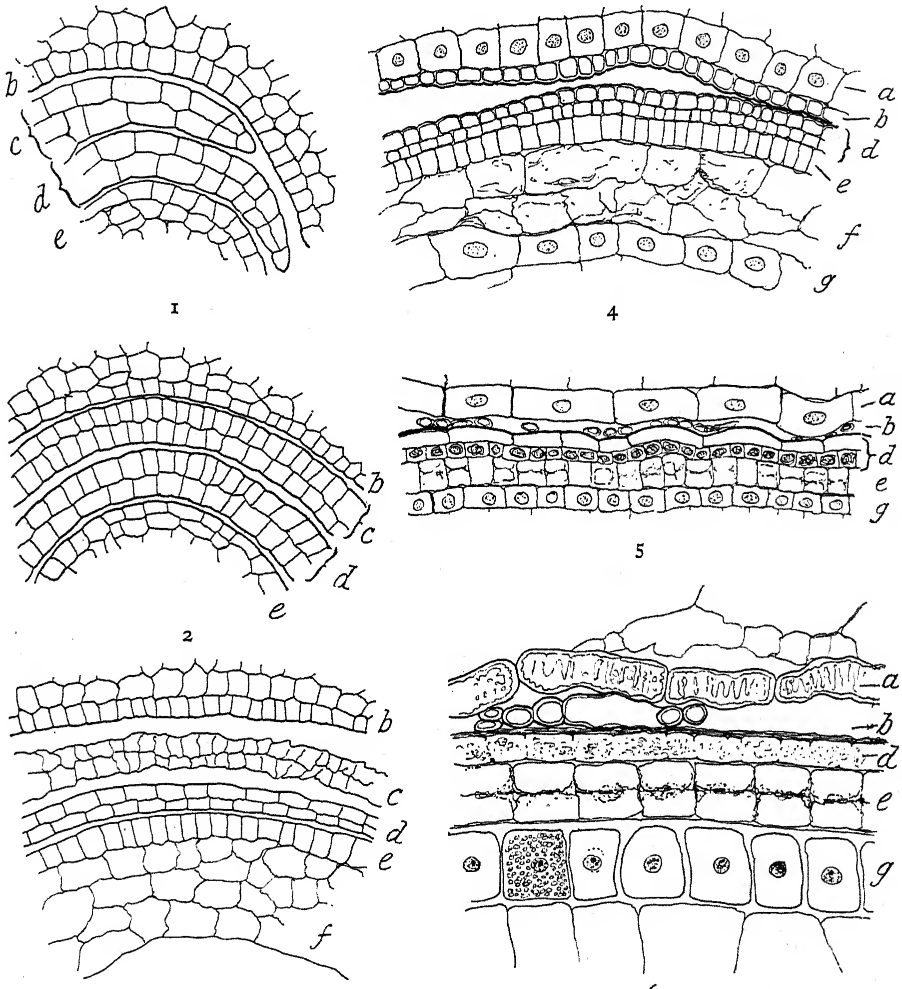


FIG. 109.—Transverse sections illustrating the changes in the inner layer of the pericarp, the integuments, and nucellus during the growth and ripening of the grain (× 270). *a*, "Cross layer" (p. 8); *b*, inner epidermis of the pericarp; *c*, outer, *d*, inner integument of the ovule; *e*, epidermis of the nucellus; *f*, cells of the nucellus; *g*, aleuron layer.

dissolved (6, *d*, Fig. 109), and as the result of the shrinkage which occurs during the final stages of drying and ripening of the grain the inner and outer walls are crushed together. The two collapsed layers representing the inner integument persist as the testa of the seed.

The wall of the ovary, up to the time of fertilisation of the ovum, is composed of thin-walled parenchyma enclosed between an outer and an inner epidermis, but changes take place in the thickness and character of its tissues as growth proceeds.

In a half-grown grain certain portions of the wall have become differentiated from the rest. The outer epidermis is then composed of cells three or four times as long as broad, stretched longitudinally, with lateral walls showing irregular beaded thickenings and a cuticle on the external surface.

The inner epidermis consists of long thin-walled cells parallel with those covering the exterior.

Between these outer and inner layers is loosely compacted parenchyma, in transverse section, three or four cells across. The tissue is colourless with the exception of a differentiated chlorophyllous " cross layer " one cell thick, which lies immediately within the inner epidermis. The cells of this layer are cylindrical, five or six times as long as broad, with rounded ends, their long axes arranged at right angles to the long axis of the grain ; each cell has an elongated nucleus and vacuolated cytoplasm, in which are imbedded a number of chloroplasts about 4 μ in diameter, which usually contain minute starch grains measuring, when fully grown, about 3 μ by 1·4 μ.

Chloroplasts are found also in some of the outer subepidermal cells in the ventral furrow of the young pericarp.

In Abyssinian purple-grained wheat, the cell-sap of the cross layer and a few of the cells of the parenchyma adjacent to it contain anthocyan.

As the grain matures the minute starch grains (1-2 μ in diameter) present in the parenchyma of the young pericarp disappear gradually from the apex of the ovary towards the base, remaining longest in the portion covering the embryo and in the ventral furrow: the cuticle and thickening of the outer epidermal cell walls then become more marked.

The cells of the inner epidermis do not keep pace with the increase in area of the inner surface of the ovary, and are torn asunder, appearing in the ripe pericarp as a series of isolated sinuous cells—the " tube-cells " of Vogl (Fig. 5)—which in some parts are widely separated from each other.

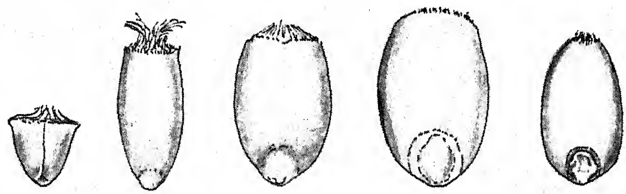
The cells of the " cross layer " lose their green colour, their contents disappear, and their walls increase greatly in thickness and develop narrow transverse pits (Figs. 3, 109).

The rest of the parenchyma of the pericarp shrivels, and ultimately forms an irregular crushed layer between the strong epidermis and the thick-walled " cross layer " (Fig. 3).

Ripening of the Grain

The ovary of the fully developed flower before fertilisation resembles a blunt inverted cone, and is about 1 mm. long and 1 mm. across the broad stylar end (Fig. 110).

After fertilisation it increases in volume from day to day, reaching



a *b* *c* *d* *e*

Fig. 110.—Grain showing changes in size and form during development (× 2·7). *a*, June 27; *b*, July 4; *c*, July 12; *d*, August 1; *e*, August 15 (ripe).

its maximum size in four or five weeks, after which it shrinks through the loss of water during the next three or four weeks until the grain is ripe (Fig. 110).

The following measurements record the changes in length, breadth, from side to side, and thickness measured from dorsal to ventral side of developing grains.

"SWAN" WHEAT (*T. vulgare*)

1914.	Length.	Breadth.	Thickness.
	mm.	mm.	mm.
June 27	4	3	2
July 4	6·75	3·5	2·5
,, 12	7	4·5	3·5
,, 19	7	4·5	3·5
August 1	7·75-8	5·25	4
,, 8	7·75-8	4·5-4·8	4
,, 15 (ripe) . .	8·6	4·1	3·5

In the early stages of ripening the length, breadth, and thickness all increase more or less uniformly, but in the later stages the length increases while the diameters are reduced, the grain becoming longer and narrower.

In addition to a change of volume and form there is a gradual alteration in the weight, water content, and the amount of dry matter in the grain as ripening proceeds. These variations are given below.

1916.	Volume of 100 Grains.	Weight of 100 Grains.	Water Content.	Dry Matter.
	c.c.	gr.	per cent.	per cent.
July 7 . . .	3·36	2·84	70·61	29·39
,, 14 . . .	4·54	4·65	68·97	31·03
,, 21 . . .	5·79	6·00	60·86	39·14
,, 28 . . .	6·42	7·37	52·66	47·34
Aug. 4 . . .	5·86	7·66	40·75	59·25
,, 11 . . .	3·95	4·86 *	15·41	84·59
,, 18 . . .	3·47	4·63 *	11·93	88·07

* Ripe grain from sheaves in the field.

The volume and weight both increase until a maximum is reached and then decrease; the volume was greatest in the grains examined on July 28. The water content decreased from 70 to about 50 per cent during July; at the time of cutting (August 7) the amount present was 40 per cent, that in the grain taken from sheaves two to three days after cutting, 15 per cent, while it was reduced to 12 per cent in the grain of the crop cut and left in the field ten to twelve days.

The dry matter increased from the beginning to the end of the development and ripening of the grain.

The weight of the individual grains also continued to increase up to August 4, a few days before harvest, but rapidly fell after cutting, through loss of water.

In the week July 28 to August 4, the weight of the grain increased, while the volume and water content decreased; the migration of starch and other substances into it during this period more than balanced the loss of water.

These changes in developing grains exhibit the same general progression each season, but investigations carried on during several years show that they do not always proceed at the same rate, the loss of water and the accumulation of dry matter being accelerated or retarded by variations in the amount of sunlight, and the temperature and dryness of the atmosphere.

Although the ripening changes of the plant proceed gradually without any definite break in continuity, four stages may be recognised, viz. the *milk-ripe*, *yellow-ripe*, *ripe*, and *dead-ripe* stages.

In the *milk-ripe* stage the crop has a green appearance. The lower leaves of the plants are dead, but the blades of the three upper leaves, the higher internodes, and the ears are living and green; only on the edges or tips of the leaves are there any visible signs of ripening in the form of yellowish spots and stripes.

The leaf-sheaths are green and their swollen nodal portions plump and sappy.

The glumes and pericarp of the grain are also green, the chlorophyllous layer of the latter showing through the outer colourless tissue.

At this stage the grain has attained its maximum volume and highest water content; the vacuoles of the endosperm tissue contain watery sap, and starch grains are abundant in the cells; from it can be squeezed a milk-like liquid whose whiteness is due to numerous starch grains present in it.

The several parts of the embryo are completely differentiated, but have not quite reached their full development, and although grains harvested now germinate readily, the young plants are somewhat weak.

In the *yellow-ripe* stage the crop has changed to a golden tint except in the purple-strawed forms which are a pinkish purple colour. The straw is smooth and shining, tough and pliable.

The chlorophyll has disappeared from all parts of the leaves, except the thick nodal portions of the upper leaf-sheaths, which still remain swollen and green, those of the lower leaf-sheath being shrunken and brownish.

The glumes have assumed their characteristic ripe tint.

As ripening proceeds, the chlorophyll in the pericarp of the grain gradually disappears, first from the upper part and dorsal side, and later, from the lower part and the furrow; in the yellow-ripe stage it is no longer to be seen.

The grain can be crushed between the thumb and finger-nail, the contents, however, are not milky, but soft, and they knead like dough.

This is the best stage of ripeness in which a crop of wheat should be cut; assimilation is at an end, and there is no gain in weight by leaving it longer. The danger of losing some of the grain by "shattering" is also reduced by harvesting at this period of development.

The *ripe* stage is reached in dry, clear weather three or four days after the yellow-ripe stage. The thick basal portions of the leaf-sheaths are now dry and shrunken.

The grain readily parts from the rachilla and is liable to shake out of the glumes. It is firm, and though it may be dented by pressure of the thumb-nail, it is not easily crushed. Its characteristic colour has become more distinct, the yellow grains paler, the red grains somewhat darker, and the flinty or mealy character of the endosperm is clearly emphasised.

In the *dead-ripe* stage the straw becomes dull, more and more brittle and dirty the longer it is left uncut.

The axis of the ear is liable to become brittle and in some forms the ears fall off or break in pieces; the grain "shatters" easily, and much is lost in harvesting the crop if left as late as this.

The grain is hard and breaks into angular fragments when crushed.

If damp weather prevails the plant is soon discoloured by the growth of fungi.

The time which elapses between the escape of the ear from the upper leaf-sheath and the ripening of the grain varies with the kind of wheat, the date of appearance of the ear, and the climatic conditions of the locality where the crop is grown.

It is somewhat remarkable that many late forms with a long, vegetative period of growth tend to develop their grain more quickly than the early or rapid-growing forms, the latter also appearing to require a higher temperature and greater intensity of sunlight for the process than the former.

Sown in the ordinary season in autumn or spring at Reading, the time between " earing " and ripening is usually from 55 to 63 days. By reference to the tables on pp. 86-88, however, it is seen that the period may extend to 80 days or more in the case of certain wheats sown very early or very late, especially in seasons (such as 1912) which prove to be dull, wet or cool in late summer.

By sowing at abnormal times the production of ears may be delayed until the end of September or later, but in such cases the grain does not ripen, as the growth is checked by the low temperature and diminished light of autumn.

Wheats ripen best at Reading between the last week in July and the second week in August.

The earliest date at which ripening occurs in any wheat at Reading is during the last ten days of July, the ears in such cases escaping from their sheaths about the first week of June.

The latest period is about the middle of September, and to ripen by that time the ears must appear not later than the early part of July.

Late or autumn forms of wheat at Reading must be sown before the middle of March, or they rarely ripen grain in that season, although when sown as late as April 5 they develop ears in due course in August or September.

Most early or spring forms must be sown before the middle of April or they will not ripen grain, although some of them produce ears in late summer if sown as late as the first week of July.

Fife wheat sown at Reading between August and the first week of December usually ripens in the first ten days of the following August; sown in January, February, or March, ripening occurs between the middle and the end of August (p. 86).

The later forms of English autumn wheats sown between August and December ripen about the middle of August; sown in January or February the ripening may be delayed until the end of August or

beginning of September. Some groups of wheat are intermediate between these in their ripening period.

There is a close correlation between the point at which the first flowers open on an ear of wheat and the region in which the heaviest and largest grains are found. The point differs a little with the race and form of wheat.

In *T. vulgare* the heaviest spikelets and grains occur in the middle third of the ear, in winter wheats not far from the union of the middle and lower third, in spring wheats slightly higher and nearer the middle of the ear.

The average 100-grain weight increases up to the point where the heaviest grains are found, and decreases upwards to the tip.

The average weight of the grain is higher in the lower than in the upper half.

In spikelets with more than three grains the second grain is generally the heaviest, and the third and fourth lighter than the first.

PART II

CHAPTER IX

CLASSIFICATION

PRE-LINNEAN botanists of the sixteenth and seventeenth centuries generally adopted the classification of the cultivated wheats suggested by Columella, dividing them into two sections, namely:

I. Species of *Triticum*, or wheats whose ears have a tough rachis and grain so loosely invested by the chaff that they fall out when the ears are thrashed, and

II. Species of *Zea*, whose ears possess a fragile rachis, which breaks into short lengths, and whose grains are so firmly enclosed by the glumes that they are separated from the latter with difficulty.

Those comprising the *Zea* section are at the present day often spoken of as "spelt" wheats, the term "spelt" being used in a generic sense and embracing Small Spelt (*T. monococcum*), Emmer (*T. dicoccum*), and Common Spelt (*T. Spelta*).

Linnaeus, however, placed all the cultivated wheats under the single genus *Triticum*, of which in the first edition of his *Species Plantarum* (1753) he mentions five species, viz.:

1. *T. aestivum* (Bearded Spring Wheat).
2. *T. hybernum* (Beardless Winter Wheat).
3. *T. turgidum*.
4. *T. Spelta*—Zea dicoccos vel spelta major of C. Bauhin.
5. *T. monococcum*—Zea Briza dicta, vel monococcus germanica of C. Bauhin.

In the second edition of his *Species Plantarum* (1764) he added *T. polonicum*, adopting Plukenet's specific name.

Later in the Supplement (1781) his son introduced the species *T. compositum*, a form of *T. turgidum* with proliferous ears (2, Fig. 160).

In 1786 Lamarck (*Encyclop. Méthodique*, vol. ii. p. 554) recognised five species, viz.:

1. *T. sativum*, embracing the Linnean species *T. aestivum*, *T. hybernum*, and *T. turgidum*.
2. *T. compositum*, L. fils.
3. *T. polonicum*, L.
4. *T. Spelta*, L.
5. *T. monococcum*, L.

In the following year (1787) Villars, in the *Histoire des plantes de Dauphiné* (vol. ii. p. 153), referred all the wheats to seven species, viz.:

1. *T. vulgare* (*T. aestivum*, L.).
2. *T. touzelle*, Gouan hort. 57 (*T. hybernum*, L.).
3. *T. turgidum*, L.
4. *T. maximum* (a wheat resembling *T. polonicum*).
5. *T. compositum*, L.
6. *T. Spelta*, L.
7. *T. monococcum*, L.

Schrank in 1789 (*Baier. Fl.* vol. i. p. 387) recognised only two species, viz.:

1. *T. cereale*, with the two varieties: (α) *aestivum*, (β) *hybernum*.
2. *T. Spelta*.

He says that he thinks "Emmer which is cultivated in Würtemberg belongs to this, if it is not a distinct species; I call it * dicoccon."

Host in 1805 (*Gram. Austr.* vol. iii.) extended the list to eleven species, viz.:

1. *T. vulgare* (= *T. aestivum* and *T. hybernum*).
2. *T. compositum*, L.
3. *T. turgidum*, L.
4. *T. Zea* (= *T. Spelta*, L.)
5. *T. Spelta* (= *T. amyleum*, Ser.).
6. *T. polonicum*, L.
7. *T. monococcum*, L.

and added in 1809 (vol. iv.)

8. *T. hordeiforme* (a form of *T. durum*, Desf.).
9. *T. villosum* (a pubescent white-glumed *T. durum*, Desf.).
10. *T. compactum*.
11. *T. atratum* (a variety of *T. amyleum*, Ser., with dark brown or black pubescent glumes).

Host was the first botanist who united the Linnean *T. aestivum* and *T. hybernum* under one species (*T. vulgare*). Persoon, in his *Synopsis Plantarum* (1805), united them with *T. durum* under the name *T. sativum*.

In 1809 Bayle-Barelle (*Mon. agr. dei cereali*) described eleven species in two sections, viz.:

Section I

1. *T. compositum*, L. fils.
2. *T. turgidum*, L.
3. *T. polonicum*, L.
4. *T. cerulescens* (= a variety of *T. durum*, Desf.).
5. *T. tomentosum* (= a variety of *T. durum*, Desf., or *T. turgidum*, L.).
6. *T. candidissimum*, Arduini (= a red-grained variety of *T. durum*, Desf., with white glabrous and shining glumes), which he considers the *Siligo* of Varro, Pliny, and Columella.
7. *T. creticum silvestre* (= *T. sylvestre creticum*, C. Bauhin, and awnless *T. compactum*, Host).

8. *T. sativum*, Pers. (*T. hybernum*, L.) This he subdivides into four varieties:
   - i. *T. sat. varietas mutica alba.*
   - ii. *T. sat. varietas mutica alba tomentosa* (*T. anglicum*, Arduini).
   - iii. *T. sat. varietas ruffa aristata.*
   - iv. *T. sat. varietas ruffa mutica.*

Section II

9. *T. farrum.* He classes the *Zea* of Galen, Dioscorides, and Theophrastus with this and states that it is often confused with *T. Spelta*, L.
10. *T. monococcum.*
11. *T. Spelta.*

with three others in an Appendix, viz.:

T. bicorne, Forskal. | *T. tumonia*, Beguillet. | *T. Blat de Caure*, Spagnuoli.

In 1816 Lagasca (*Gen. et. sp. pl.* 82) described sixteen species, viz.:

1. *T. monococcum*, L.
2. *T. Cienfuegos.*
3. *T. Bauhini.*
4. *T. Spelta*, L.
5. *T. hybernum*, L.
6. *T. aestivum*, L.
7. *T. Linneanum.*
8. *T. turgidum*, L.
9. *T. fastuosum.*
10. *T. Gaertnerianum.*
11. *T. platystachyum.*
12. *T. cochleare.*
13. *T. Cevallos.*
14. *T. durum*, Desf.
15. *T. polonicum*, L.
16. *T. spinulosum.*

The first four were "spelt wheats" with a fragile rachis, the last on the list possessing long foliaceous glumes presumably like those of *T. polonicum.*

Clemente, in an edition of *Herrera's Agricultura general* (Madrid, 1808), described twenty species.

Eight of them (Nos. 3, 4, 12, 14, 15, 16, 17, and 19), although given as his own species, bear the same name as those published by Lagasca two years previously: five, namely, Nos. 2, 6, 7, 9, and 11, are new.

1. *T. monococcum*, L. Pequeña Escaña o escaña menor lampiño.
2. *T. Horneman.* A pubescent *T. monococcum.* Pequeña Escaña velloso.
3. *T. Cienfuegos.* A form of *T. Spelta.* Escaña melliza ó de dos Carreras: escandia; esprilla bassona.
4. *T. Bauhini.* A form of *T. Spelta* with dense ears. Escaña mazzoral.
5. *T. Spelta*, L. Bearded. Escanda lampiña; escaña grande.
6. *T. Forskal.* A pubescent *T. Spelta.* Escanda villosa; escaña mayor peluda.
7. *T. Arias.* Red and white awnless *T. Spelta.* Escanda mocho.
8. *T. hibernum*, L. Beardless *T. vulgare.* Chamorro comun, Pelon mocho.
9. *T. Koeleri.* An awnless pubescent *T. vulgare.* *T. sativum hybernum sardonicum* of Koeler and others. Chamorro velloso.

10. *T. aestivum*, L. Bearded spring *T. vulgare*. Candeal lampiño, Tremesino, Hembrilla, Jeja.
11. *T. Horstianum*. A bearded pubescent *T. vulgare*. Candeal velloso.
12. *T. Linneanum*. A form of *T. turgidum*. Redondillo lampiño.
13. *T. turgidum*, L. Redondillo velloso.
14. *T. Gaertnerianum*. Fanfarron lampiño.
15. *T. platystachyon*. Chapado ó chapado lampiño.
16. *T. cochleare*. Cuchareta ó chapado villosa.
17. *T. Cevallos*. Moro ó moruno lampiño.
18. *T. durum*, Desf. Moruno ó moro velloso.
19. *T. fastuosum*. Fanfarron velloso ; Dicho.
20. *T. polonicum*, L. Trigo polonia ó Polago.

In 1817 Roemer and Schultes (*System. veg.*) recognised twenty-one species, most of them from Lagasca and Host, the only new one being *T. siculum*, a species allied to *T. hordeiforme*, Host (*T. durum*, Desf.).

In his *Characteristica et descriptiones Cerealium* (1818) Schübler gives the following sixteen species, which he groups in two sections :

SECTION I.—With loosely invested grain

1. *T. muticum :*
   (*a*) aestivum. | (*b*) hybernum, L.
2. *T. aristatum :*
   (*a*) aestivum, L. | (*b*) hybernum.
3. *T. sibiricum*. Siberian spring wheat, an early *T. vulgare* (?).
4. *T. velutinum*.
5. *T. compactum*, Host :
   (*a*) aristatum. Bengelweizen awned.
   (*b*) muticum. Bengelweizen awnless.
6. *T. turgidum*, L.
7. *T. hordeiforme*, Host. (A form of *T. durum*, Desf.)
8. *T. durum*, Lagasca. Arabian winter wheat : a form of *T. durum*, Desf.
9. *T. siculum*, Schmidt. (Sicilian wheat.)
10. *T. compositum*, L. | 11. *T. polonicum*, L.

SECTION II.—With "Spelt" ears

12. *T. Spelta :*
   (*a*) mutica.
      α. alba.
      β. rubra.
   (*b*) aristata.
   (*c*) velutina.
   (*d*) aestiva.
13. *T. monococcum*, L.
14. *T. dicoccum*.
   (*a*) album. | (*b*) rufum.
15. *T. atratum*, Host.
16. *T. tricoccum*.

Seringe in 1818, in his *Mélanges botaniques* and *Monographie des céréales de la Suisse*, described eight species in two sections, viz. :

Section I.—Frumenta

1. *T. vulgare.*
2. *T. turgidum.*
3. *T. durum.*
4. *T. polonicum.*

Section II.—Speltae

5. *T. Spelta.*
6. *T. amyleum.*
7. *T. monococcum.*
8. *T. venulosum.* An apparently immature specimen collected in Egypt and sent to Seringe by Professor Desfontaines. Seringe considered it allied to *T. monococcum*, but larger with anastomosing prominent veins ; probably a form of Indo-Abyssinian *T. dicoccum.*

In 1824 Metzger, in his *Europaeische Cerealien*, adopted the species recognised by Seringe in his *Monographie des céréales de la Suisse*, only leaving out the doubtful *T. venulosum*, and in 1827 Link (*Hort. berol.*) adopted the same classification with the addition of *T. compactum.*

Later, Seringe, in his *Céréales européennes* (1841–42), classified the eight species of wheats of his earlier monograph under the three genera *Triticum*, *Spelta*, and *Nivieria* thus :

Genus Triticum—

1. *T. vulgare*, Willd. (This included *T. compactum*, Host.)
2. *T. turgidum*, L.
3. *T. durum*, Desf.
4. *T. polonicum*, L.

Genus Spelta—

5. *S. vulgaris.*
6. *S. amylea.*

Genus Nivieria—

7. *N. monococcum.*
8. *N.* (?) *venulosa.*

Vilmorin in 1850 (*Catalogue méthodique et synonymique des froments*) followed the classification of Seringe and Metzger, recognising seven species, viz. :

1. *T. sativum.*
2. *T. turgidum.*
3. *T. durum.*
4. *T. polonicum.*
5. *T. Spelta.*
6. *T. amyleum.*
7. *T. monococcum.*

Alefeld in 1866 (*Landwirtschaftliche Flora*) included all wheats under the single species *T. vulgare*, except Polish wheat, which he placed in a separate genus, *Deina* (*D. polonica*).

The species *T. vulgare* he divided into nine " varietal groups," viz. :

1. *T. vulgare durum.*
2. *T. vulgare turgidum.*
3. *T. vulgare compositum.*
4. *T. vulgare compactum.*
5. *T. vulgare muticum.*
6. *T. vulgare aristatum.*
7. *T. vulgare dicoccum.*
8. *T. vulgare monococcum.*
9. *T. vulgare Spelta.*

These groups are again subdivided into varieties, to each of which he gives a triple name.

Körnicke in 1885 (*Die Arten und Varietaten des Getreides*, vol. i.) recognised three species of wheat, viz.:

1. *Triticum vulgare*, Vill. . . . Common wheat.
2. *Triticum polonicum*, L. . . . Polish wheat.
3. *Triticum monococcum*, L. . . . Einkorn or small Spelt.

He divides *T. vulgare* into six sub-species, viz.:

I. Rachis tough: grains easily separated on thrashing.

Sub-species—

1. *Triticum vulgare*, Vill. . . . Common wheat.
2. *Triticum compactum*, Host . . Dwarf wheat.
3. *Triticum turgidum*, L. . . . English wheat.
4. *Triticum durum*, L. . . . Hard (or Macaroni) wheat.

II. Rachis fragile: grain firmly enclosed in the glumes.

Sub-species—

5. *Triticum Spelta* . . . . Common Spelt.
6. *Triticum dicoccum*, Schrk. . . Emmer.

E. Hackel (Engler and Prantl's *Nat. Pfl.* vol. ii. pp. 2, 81, 84 [1887]) separated the genus *Triticum* into two sections:

Section I.: *Aegilops*, with rounded glumes, not keeled or only faintly so.
Section II.: *Sitopyros*, with sharply keeled glumes.

In the latter section, which embraces the cultivated wheats, are included three species, viz.:

1. *T. monococcum*. | 2. *T. sativum*. | 3. *T. polonicum*.

T. sativum is divided into several races as follows:

I. Rachis fragile and grain firmly invested by the glumes.

1°. Ear lax, quadrate, empty glumes with blunt keel:
(*a*) *T. sativum Spelta*.
2°. Ear denser, compressed, empty glumes sharply keeled:
(*b*) *T. sativum dicoccum*.

II. Rachis tough: grain loosely invested by the glumes.

(*c*) *T. sativum tenax*.

(*c*) *T. sativum tenax* is divided thus:

α. *T. sativum vulgare* . . . (*T. vulgare*, Vill.).
β. *T. sativum compactum* . . . (*T. compactum*, Host).
γ. *T. sativum turgidum* . . . (*T. turgidum*, L.).
δ. *T. sativum durum* . . . (*T. durum*, Desf.).

A classification similar to that of Hackel is adopted by Ascherson and Graebner (*Syn. Mitteleur. Fl.* vol. ii., 1901).

The classification adopted by most of the early authors is highly artificial, being based chiefly upon the characters of the ears and grains alone, and often had reference to comparatively few forms, or to those confined to one or two limited wheat-growing regions.

In order to obtain a wider view of the subject, and to discover the natural relationships of the cultivated wheats, I have critically examined, during the last twenty years or more, living specimens from all parts of the world.

Nearly two thousand forms have been grown annually side by side, and their morphological characters in the young and mature states, as well as their habit of growth, ripening period, susceptibility to the attacks of fungi, and other characters, have been investigated and compared.

In determining the limits of the several races, I have not only taken into account the usual morphological characters of the inflorescences, but have given especial weight to the characters of the leaves and vegetative organs generally, being convinced that these have undergone little change, and indicate natural genetic relationships more clearly than the ears and grain, the modification of which has been the special object of the cultivator from the earliest date.

I find, for example, that the length, amount, and arrangement of the hairs on the young leaf-blades are much more constant and characteristic features of a race than the size, shape, and colour of its ears and grain.

I have also taken into consideration anatomical features and the results of hybridisation, as well as archaeological evidence, and the distribution of endemic forms in the older wheat-growing areas of the Eastern Hemisphere.

Two wild species of wheat are known, and the cultivated wheats, none of which are found wild, fall into eleven natural groups. To these groups I have applied the term "race" rather than the term "species," although they might with equal justice be designated "cultivated species," for the methods used in their grouping and delimitation are the same as those adopted in the case of wild species.

My conclusions regarding the number and classification of the races of wheats are indicated below.

With the exception of the addition of the three new races, III., VII., and X., the list and the chief distinguishing characters of the groups, whether termed "races" or "species," agree closely with those given by Seringe and almost all authorities since his time.

SPECIES I.	*T. aegilopoides*, Bal. . .	Wild Small Spelt.
RACE I.	*T. monococcum*, L. . .	Small Spelt.

SPECIES II.	*T. dicoccoides*, Körn. . .	Wild Emmer.
RACE II.	*T. dicoccum*, Schübl. .	Emmer.
III.	*T. orientale*, mihi . .	Khorasan Wheat.
IV.	*T. durum*, Desf. . .	Macaroni Wheat.
V.	*T. polonicum*, L. . .	Polish Wheat.
VI.	*T. turgidum*, L. . .	Rivet or Cone Wheat.
VII.	*T. pyramidale*, mihi . .	Egyptian Cone Wheat.
VIII.	*T. vulgare*, Host . .	Bread Wheat.
IX.	*T. compactum*, Host . .	Club Wheat.
X.	*T. sphaerococcum*, mihi .	Indian Dwarf Wheat.
XI.	*T. Spelta*, L. . . .	Large Spelt or Dinkel.

DIAGNOSTIC CHARACTERS OF THE SPECIES AND RACES OF WHEATS

SPECIES I.—**Triticum aegilopoides**, Bal. Wild Small Spelt.

Coleoptile, 2-nerved.

Young shoots, erect or prostrate; young leaves blue-green or yellow-green, more or less hairy, with a line of long hairs on the summit of the longitudinal ridges.

Straw, slender; nodes clothed with white deflexed hairs.

Ear, bearded, compressed, very narrow across the face, broad across the 2-rowed profile; spikelets 1- (or 2-) grained; terminal spikelet minute and abortive; rachis very fragile and fringed along the margin with long straight hairs.

Empty glume, long, narrow, keeled to the base with stout, acute, apical tooth often turned slightly outwards; on the outer face a prominent nerve ending in a distinct secondary tooth some distance from the base of the apical tooth.

Palea, in ripe ears divided longitudinally into two halves.

Grain, small, rice-like, flinty, pointed at both ends, compressed from side to side, furrow indistinct; tip with few hairs.

RACE I.—**Triticum monococcum**, L. Small Spelt: Einkorn: Engrain.

Coleoptile, 2-nerved.

Young shoots, erect or semi-erect; young leaves yellowish-green, with very short hairs or scabrid projections on the longitudinal ridges.

Straw, slender; nodes clothed with deflexed hairs.

Ear, bearded, compressed, much narrower across the face than the 2-rowed profile; spikelets 1- (or 2-) grained; terminal spikelet minute and abortive; rachis fragile, glabrous or edges fringed with short hairs.

Empty glume, long, narrow, keeled to the base with a stout, acute, apical tooth, straight or turned slightly inwards; the prominent nerve on the outer half ends in a distinct secondary tooth some distance from the apical tooth.

Palea, divided longitudinally to the base when the ear is ripe.

Grain, as in *T. aegilopoides*, but shorter.

SPECIES II.—**Triticum dicoccoides**, Körn. Wild Emmer.

Coleoptile, usually 4-nerved.

Young shoots, prostrate; young leaves blue-green, clothed with soft hairs of nearly equal length; culm leaves yellowish-green.

Straw, slender, solid or hollow with thick walls; nodes clothed with deflexed hairs.

Ear, bearded, compressed, much narrower across the face than the 2-rowed profile; spikelets 1- to 2-grained; terminal spikelet large and frequently fertile; rachis very fragile, usually fringed along the margin with long straight hairs.

Empty glume, long, narrow, keeled to the base; apical tooth blunt or acute; the strong nerve on the outer half converging towards the base of the apical tooth and ending in a short secondary tooth.

Palea, not divided longitudinally.

Grain, very long (9-12 mm.), narrow, and flinty, somewhat triangular in section, with a conspicuous tuft of white hairs at the apex.

Race II.—**Triticum dicoccum**, Schübl. Emmer.

Coleoptile, in Indo-Abyssinian Emmers usually 4- to 6-nerved; in European Emmers 2-nerved.

Young shoots, usually erect; young leaves with soft hairs of nearly uniform length.

Straw, solid or hollow with thick walls; Indo-Abyssinian forms short, European forms taller.

Ear, bearded, compressed, narrower across the face than the 2-rowed profile; spikelets generally 2-grained; rachis fragile or tough, narrow, fringed with short hairs.

Empty glume, long and narrow, the outer face flat; keel prominent from tip to base; apical tooth in Western European forms acute and curved as in *T. durum*; in the Russian, Indian, and Abyssinian forms short and blunt.

Grain, flinty or semi-flinty, 7-9 mm. long, narrow, pointed at both ends, ventral side flat or slightly concave; cross section more or less triangular.

Race III.—**Triticum orientale**, mihi. Khorasan Wheat.

Coleoptile, 2-nerved.

Young shoots, erect; young leaves narrow, pubescent, hairs of nearly uniform length.

Straw, of medium height, solid or hollow with thick walls.

Ear, bearded, very lax, almost square; rachis tough; awns scabrid to the base, more or less deciduous.

Empty glume, long and narrow; apical tooth blunt.

Grain, white, very long (10·5-12 mm.), narrow, flinty.

Race IV.—**Triticum durum**, Desf. Macaroni Wheat.

Coleoptile, 2-nerved.

Young shoots, erect; young leaves quite glabrous or nearly so.

Straw, tall, solid or hollow with thick walls.

Ears, usually bearded, square in section or narrower across the face than the 2-rowed profile; bearded, stiff, usually erect; rachis more or less fragile; the

awns of great length, diverging slightly, and almost smooth at the base; spikelets longer and narrower than those of *T. turgidum* or *T. vulgare*.

Empty glume, long and narrow, the outer face flattish; keel curved, prominent from tip to base; apical tooth stout, generally acute and usually curved inwards; glumes somewhat readily detached from the rachis.

Grain, long and narrow, hard, more or less pointed at both ends, with a prominent dorsal ridge, endosperm flinty; somewhat triangular in section.

Transitional forms are met with having slightly hairy leaves and approximating towards *T. turgidum*, *T. vulgare*, and *T. dicoccum*, and one or two hybrids are known differing only from typical *T. durum* in having beardless ears.

Race V.—**Triticum polonicum**, L. Polish Wheat.

Coleoptile, 2-nerved.

Young shoots, erect; young leaves blue-green, glabrous or nearly so.

Straw, tall, solid or hollow with thick walls.

Ear, bearded; spikelets large, usually 1- to 2-grained; rachis somewhat fragile.

Empty glume, as long as or longer than the rest of the spikelet, narrow, 3-4 cm. long, keeled, with two small apical teeth.

Grain, very long (11-12 mm.), narrow, flinty, somewhat triangular in section.

Race VI.—**Triticum turgidum**, L. Rivet or Cone Wheat.

Coleoptile, 2-nerved.

Young shoots, erect or prostrate; young leaves clothed with soft hairs of nearly uniform length.

Straw, tall, solid or hollow with thick walls.

Ear, usually bearded, square in section or narrower across the face than the 2-rowed profile; bearded, heavy, often pendulous, and less rigid than *T. durum*; rachis tough; awns stout, very scabrid from tip to base, frequently deciduous; spikelets about as long as broad, often ripening 3-4 grains.

Empty glume, short and broad, the outer face convex, keel prominent from tip to base; apical tooth stout, usually acute and curved; glumes more firmly attached to rachis than in *T. durum*.

Grain, generally mealy, though sometimes flinty or semi-flinty; large, plump, and somewhat short, with truncate apex and high dorsal hump behind the embryo.

Race VII.—**Triticum pyramidale**, mihi. Egyptian Cone Wheat.

Coleoptile, 2-nerved.

Young shoots, erect; young leaves pubescent, hairs somewhat short; culm leaves yellowish-green.

Straw, very short, solid or hollow with thick walls.

Ear, bearded, dense, short, usually tapered towards the apex and oblong in section, wider across the 2-rowed side than across the face; rachis tough; awns scabrid to the base and sometimes deciduous.

Empty glume, keeled to the base.

Grain, usually mealy, short and narrow, somewhat pointed at the apex; dorsal hump prominent.

RACE VIII.—**Triticum vulgare**, Host. Bread Wheat.

Coleoptile, 2-nerved.

Young shoots, erect, semi-erect, or prostrate; young leaves more or less hairy, the hairs of unequal length, with a single row of long ones along the summit of some or all the longitudinal ridges.

Straw, hollow with thin walls, though forms are occasionally found with solid upper internodes.

Ear, bearded or beardless, square in section or more commonly broader across the face than the 2-rowed profile, bearded or beardless; the awns shorter than those of *T. durum* or *T. turgidum*; some entirely beardless, others classed as beardless have awns of variable length on the upper spikelets; spikelets usually about as long as broad; rachis tough.

Empty glume, broad, the outer face convex, keeled from tip to base or in the upper half only; apical tooth in the bearded forms short, acute, or sometimes prolonged into an awn (1-4 cm. long), in the beardless forms usually short and blunter.

Grain, very varied in form and size; flinty or mealy; usually plump with bluntish apex, rounded on the dorsal side without prominent hump or ridge.

RACE IX.—**Triticum compactum**, Host. Club Wheat.

Coleoptile, 2-nerved.

Young shoots, leaves, straw, and glumes as in *T. vulgare*.

Straw, hollow, very variable in length.

Ear, bearded or beardless, short and dense from 3·5 to 6 cm. long, density 40-50; spikelets broad and short, often containing 3-4 grains; rachis tough.

Empty glume, as in *T. vulgare*.

Grain, generally soft and mealy, plump, small, variable in shape, some with prominent dorsal hump like those of *T. turgidum*.

RACE X.—**Triticum sphaerococcum**, mihi. Indian Dwarf Wheat.

Coleoptile, 2-nerved.

Young shoots, erect; young leaves as in *T. vulgare*.

Straw, very short, stiff, erect, and hollow, usually not more than 65-70 cm. long, except where irrigated; culm leaves rigid and somewhat erect.

Ear, bearded or beardless, stiff, erect, 4-6 cm. long, not so dense as *T. compactum*; awns of bearded forms shorter and stouter than those of *T. compactum*; rachis tough; length and breadth of the spikelets about equal.

Empty glume, broad and short, inflated, with strong curved scabrid apical tooth.

Grain, very short (4-5 mm. long), flinty, often angular on account of pressure of the glumes.

Race XI.—**Triticum Spelta,** L. Large Spelt or Dinkel.

Coleoptile, 2-nerved.

Young shoots, erect or prostrate; young leaves dark green with few hairs arranged as in *T. vulgare*.

Straw, stout and hollow.

Ear, very lax, bearded with short awns or beardless; rachis broad and stout, convex on one side, flat or concave on the other, fragile, breaking transversely below each spikelet; spikelets narrow with 2-3 grains.

Empty glume, firm, with broad truncate apex; apical tooth short and blunt; prominent lateral nerve ending in a blunt projection.

Grain, long, usually flinty, somewhat pointed at both ends, apex with tuft of hair, ventral surface flattened or hollowed slightly, furrow shallow.

Variety.—The several races of wheats are subdivided into smaller groups or *varieties*, these being founded upon a number of obvious hereditary morphological differences of the ears and grain.

The presence or absence of awns, the colour, smoothness, and hairiness of the chaff, and other characters were utilised in subdividing the races by Seringe, Metzger, Vilmorin, and others. The scheme adopted by Körnicke I have found most convenient and clearly defined for taxonomic purposes, and it carries the classification further without loss of clearness than any previous scheme.

The following are the characters on which varieties are based:

1. Presence or absence of awns.
2. Colour of glumes (white, red, or black).
3. Colour of the awn (white, red, or black).
4. Glabrous or pubescent glumes.
5. Colour of grain (white or red).

In the races *T. turgidum* and *T. dicoccum* in which branching of the rachis is hereditary the division into simple and compound ears is made.

While all the characters mentioned are hereditary, the extent of their development is affected in greater or lesser degree by external conditions, a fact to be borne in mind when a decision has to be made in respect of the variety under which a particular individual is to be classed.

Beardless wheats, as explained in another place (p. 104), are either truly awnless or the awns of the flowering glume are not more than one or two cm. long, the bearded forms of the same race having awns three or four times this length. In practice there is no risk of confusing the bearded with the beardless condition.

The glume colour is constant, but in some seasons the black tint is greatly subdued, or missing altogether, and the pale red varieties are sometimes difficult to separate from those with white chaff.

The awns of varieties with white and red chaff are either white or red like the glume, or black. The black pigment, however, is so variable in

its appearance in this country that plants belonging to varieties differing only in the colour of the awn cannot be accurately classified except after observations extending over two or three seasons at least.

Grain colour is a hereditary character subject to little variation and usually determined without much trouble. Only in Macaroni Wheats is it sometimes extremely difficult to distinguish the pale red flinty grains from those which are white with yellowish translucent endosperm.

The amount and character of the hair on the glumes is of good diagnostic value and in most cases is readily seen. Care, however, is needed where the hair is short and sparsely distributed.

FORM.—Wheats belonging to the same variety as defined by reference to the scheme just mentioned differ among themselves in the length of the ear and straw, the density of the ear, the shape of the empty glumes, the earliness and lateness of ripening, and in other hereditary features both morphological and physiological. For example, the variety of *T. vulgare* with beardless ears, white glabrous chaff, and red grain (var. *lutescens*) includes the wheats known among farmers as Purple straw, Red Fife, Squarehead, Briquet Jaune, Warden, and many others.

These names represent, or ought to represent, the progeny of a single individual, the origin of which may, or may not, be known with certainty. To each of these I apply the term *form*, in place of the terms *variety*, *type*, or *sort* used by others.

Many attempts have been made to group these forms for purposes of easy reference and identification, but none of the various schemes proposed are of more than limited application.

In the case of the rarer varieties in which only a small number of forms are known the task is not insuperable, and simple keys for the identification of the several forms may be readily devised; but in the varieties *erythrospermum* (bearded ears, with white glabrous glumes and red grain), *ferrugineum* (bearded ears, with red glabrous glumes and red grain), *lutescens*, and *milturum* (the corresponding beardless varieties) of *T. vulgare*, and in lesser degree the varieties *leucurum* (ears with white glabrous glumes and white grain) and *hordeiforme* (ears with red glabrous glumes and white grain) of *T. durum*, the existing forms are so numerous and intergrade in almost all their characters between one extreme and another that the formation of clearly defined groups or classes is a problem of the greatest difficulty, if not practically impossible.

The most useful way of dealing with such extensive varieties is to make a separate classification for the forms of it cultivated in each country. In order to accomplish this, and for purposes of identification of the separate forms, detailed descriptions are needed. These should be made after a study of the living plants grown side by side during several seasons and should take cognisance of the following characters:

Young Tillered Plant.—Habit of shoots, erect, sloping, or prostrate; colour of the leaves; leaf-surface, glabrous or pubescent, and distribution of the hairs on the longitudinal ridges.

Straw.—Its average height; whether hollow or solid, rough or smooth.

In the description of wheats given later I have adopted the following general table of straw lengths:

Very short . . .	Below 24 in.
Short	24-34 in.
Medium . . .	34-44 „
Tall	44-54 „
Very tall . . .	Over 54 in.

Ear.—Average length; breadth across the face and width of the two-ranked side: whether specially glaucous or non-glaucous and yellowish-green. In awned forms the length of the awns; in beardless forms whether "tip-bearded" or truly awnless.

The general form, whether uniform in diameter, clubbed at the apex, or tapered either from base upward, or from middle upward and downward.

Ear "density" and number of spikelets.

It is usual to define the "density" (D) of an ear as the number of spikelets per 10 cm. length of the rachis. The total length in centimetres (L) of 10 normally developed ears is measured and the number of spikelets (N) counted; from these determinations the density is calculated thus:

$$D = \frac{N \times 10}{L}.$$

In the descriptions of wheats given later the following table of densities is adopted:

Lax	D below 22.
Medium . . .	22-28.
Dense	28-34.
Very dense . . .	above 34.

Very dense ears are characteristic of the Club Wheats; a few are seen in the Bread Wheats, but they are rare among the Macaroni and Rivet Wheats and unknown in Emmer and Large or Small Spelt.

The density of the ear is subject to the ordinary fluctuating variation and is influenced to some extent by climatic changes and alterations in the water-supply and nutrition of the plant.

The application of large amounts of nitrogenous fertilisers tends to lengthen the internodes of the rachis, but I have failed to produce by the most drastic manurial treatment a lax ear in plants of *T. compactum* or in any Squarehead *vulgare* wheat.

I find that the ear-density of some forms of Bread Wheat from India and Australia is more readily influenced by external conditions than that of any other wheats.

Although the "density" in some countries appears to be so variable that it is of little or no value there for purposes of classification, in other regions it is practically constant under all ordinary conditions of cultivation, and of the greatest service in assisting in the identification of the various forms.

Empty Glume.—The form of the empty glume is one of the most constant characters of wheats, and of the greatest value in distinguishing nearly related forms. In some cases the glumes at the base, middle, and tip of the ear are slightly different in shape and length of the apical or keel tooth, but the glumes from the middle spikelets of ears belonging to plants of the same form are almost exactly alike, and different from those taken from the same parts of the ears of different forms. In some the upper part of the glume is broad, in others it is narrow; the apical tooth has a characteristic form and size, and the amount of its curvature inward or outward is also a constant feature. These forms unfortunately cannot be adequately described, but must be illustrated.

Grain.—Its colour, flintiness or mealiness, shape and size.

Other characters which it is important to notice are—

(1) Time at which the ear appears;

(2) The tillering capacity; and

(3) Resistance to frost, drought, and attacks of insects and fungi.

Earliness and Lateness.—Wheats are often classified by the practical agriculturist into early, mid-season, and late varieties, the terms referring to the time when the grain is fully developed and ripe. The period at which this stage is reached is chiefly dependent upon latitude and climatic conditions and subject to very considerable variation. For example, the same variety of wheat sown at the same date in the same locality may ripen its grain from 15 to 20 days or more earlier or later in one season than another, the grain ripening off quickly in a bright dry hot summer, the process being very much delayed by damp dull weather.

A much more accurate classification is made by referring the terms early, mid-season, and late to the time at which the ear escapes from the upper leaf-sheath. This time for any particular variety grown at any definite locality in England does not vary more than four or five days in any season even when the sowing is carried out during the period extending from September to December. When the sowing is later than this, say in January or early February, the time of appearance of the ear is rarely delayed more than about a week.

For details of the time usually elapsing between "earing" and ripening of the grain, see p. 142.

In the descriptions of wheats in the succeeding chapters I have adopted the following classification based on observations of more than 1500 forms grown for several years at Reading :

	Date of Earing.
Very early . . .	before May 24.
Early	May 24-31.
Mid-season . . .	June 1-7.
Late	June 8-15.
Very late . . .	after June 15.

This system of classification holds good for all districts and an early or late variety will bear the same relationship to each other in regard to the time of earing, wherever grown, though the actual dates to which these terms correspond will depend upon the latitude and climate of the place of growth.

Early forms always have the erect habit, while late forms are prostrate (see p. 69).

Spring and *Winter Wheats*.—At Reading, where the average minimum winter temperature rarely falls below $-3°$ or $-4°$ C., I have always sown all kinds of wheats in autumn and have rarely observed any damage by frost, even among the most delicate kinds.

There is, however, considerable difference among wheats in regard to their resistance to frost, some being killed outright by temperatures which others will withstand without damage.

Many wheats are little injured at $-10°$ to $-15°$ C., but suffer when the temperature falls much below this.

In cold climates the differences are readily determined, and farmers term the sorts which can be sown in autumn " Winter " wheats, applying the term " Spring " to those which are delicate and must be sown after the winter has passed.

Varieties of *T. dicoccum*, *T. orientale*, *T. durum*, *T. polonicum*, *T. turgidum*, and *T. pyramidale* are usually delicate ; on the other hand, *T. sphaerococcum*, *T. Spelta*, and *T. monococcum* are hardy races. Some forms of *T. compactum* and *T. vulgare* are also hardy, while others are tender and die out in severe continental winters. Of these, the rapid-growing forms with the erect habit (p. 69) and broad leaves are usually delicate, while the slower-growing, late-ripening sorts with narrow leaves which lie close to the ground are hardy.

Sinz found that Winter wheats showing great resistance to frosts transpire less, have firmer tissues and higher dry-matter content than Spring forms.

I have frequently observed that hares and rabbits pick out and eat typical Winter wheats before touching the Spring forms when both are grown in the same field.

Nomenclature of Forms.—The nomenclature of wheats in all countries is in hopeless confusion; the same form is frequently found under many different names, and totally different forms are often given the same name. The trouble is not modern, for mediaeval names for the same form of wheat are abundant: it has, however, increased in recent times, and there is no prospect that it will ever cease.

Some of the evil effects of the confusion might be mitigated by detailed and illustrated descriptions of the wheats of each country, and the use of the name of an old-established form for another form belonging to a different *variety* should be prohibited. For example, the name "Velvet Chaff" sometimes given to "Preston," a smooth-glumed form, should not be allowed, nor should the name "Browick," originally given to a red-chaffed form, be permitted for a white-glumed wheat as at present in England.

The application of a new name to an old form cannot be prevented, but official lists of synonyms and names of forms found after extended trials to be closely similar in morphological characters would be of much service to the present generation and of value in the future.

CHAPTER X

WILD SMALL SPELT

Triticum aegilopoides, Bal. *ex* Körn. (*aegilopodioides*, sphalm.). *Handb. d. Getreideb.* i. 109 (1885).

Crithodium aegilopoides. Link in *Linnaea*, ix. 132 (1834).
Triticum boeoticum, Boiss. *Diagn.* ser. i. fasc. 13, p. 69 (1853).
Aegilops Crithodium, Steud. *Syn. Gram.* 355 (1855).
Triticum monococcum, β. *lasiorrachis*, Boiss. *Fl. Or.* v. 673 (1884).
T. monococcum, A. *aegilopoides*, Asch. u. Graeb. *Syn.* ii. 701 (1901).

THIS wild species of *Triticum* was first described under the name *Crithodium aegilopoides* by Link, who found it in Greece between Nauplia and Corinth in 1833.

It is a widely distributed grass on the sides of low hills in Thessaly, Boeotia, and Achaia in Greece, in South Bulgaria, and on loamy soils in vineyards in Southern Serbia. Three varieties of it were discovered by Larionow in 1909 near Balaklava in the Crimea, and the variety of *T. monococcum* mentioned by Marschall Bieberstein (*Fl. Tauro-caucas.* vol. i. p. 85) as occurring wild in the Crimea and Eastern Caucasus was probably the same species. The species is also met with throughout Asia Minor extending in Kurdistan to the western border of Persia.

There is no doubt that it is from some of the varieties of this wild species that the cultivated Small Spelt (*Triticum monococcum*, L.) has been derived.

GENERAL CHARACTERS OF *T. aegilopoides*, Bal.

The coleoptile is usually purple, the shoots of the young plants in some forms erect, in others prostrate. The culms are erect, solid or hollow with thick walls, elastic and slender, from 40 to 160 cm. (15-60 inches) high, smooth except at the nodes, which are covered with white deflexed hairs ; the upper internode is exceptionally long, in some forms reaching a length of 65 cm. in culms whose total length is not more than 100 cm.

The blades of the young plants are narrow (3-6 mm. across), those of

the culm leaves broader (5-15 mm. across), their surfaces in most plants being clothed with soft short hairs, among which are longer hairs sparsely distributed along the summit of the longitudinal ridges (*a*, Fig. 111) and on the margins of the leaves. The leaf-sheaths, which are striate, are pubescent in some cases and glabrous in others. The auricles of the lower leaves are fringed with long hairs.

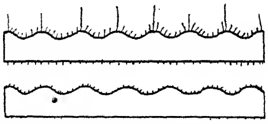


FIG. 111.—Diagrammatic transverse sections of young leaves of (*a*) *T. aegilopoides*, (*b*) *T. monococcum*.

"Shooting," or the escape of the ears from the upper leaf-sheaths, occurs at Reading about June 20, in this respect resembling the cultivated "Engrain double" (*T. monococcum*).

The ears are flat, consisting of two rows of spikelets closely arranged on opposite sides of a flattened and jointed rachis. They are from 5 to 11 cm. long, ·45-·9 cm. broad, and ·2-·25 cm. thick, and possess from 12 to 30 or more spikelets. The density (D) or number of spikelets per 10 cm. of rachis varies from 25 to 50, the Asiatic varieties having the laxest ears.

The rachis is smooth, but its edges are fringed with a line of longer or shorter hairs, and a tuft of long whitish hairs (from 1·5 to 3 mm. long) is attached to it in front of the base of each spikelet. When ripe it is very brittle, and separates at the joints into short pieces about 3 mm. long and 1 mm. broad to the upper end of each of which is attached a single spikelet. Disarticulation of the ears proceeds from the tip towards the base, the apical spikelets often falling while the basal ones are still green.

The terminal spikelet of the ear is abortive. The lateral spikelets are two-flowered, the lower flower fertile, the upper one usually sterile; they measure about 9 mm. long, 2-2·5 mm. broad, and 1 mm. thick.

When two caryopses ripen in the spikelet the upper one is the larger and germinates more rapidly than the lower one, even when both are stripped from their enclosing glumes.

The glumes are yellowish, reddish, or black, usually pubescent, but in some forms they are glabrous.

The empty glume (7-8 mm. long) is ovate, the outer half somewhat broad and truncate, with a scabrid keel terminating in a triangular tooth about 1·5-2 mm. long, which is usually bent outwards especially in unripe ears; it possesses a strong lateral nerve which ends in a small tooth ·5 mm. long (Fig. 112).

The flowering glume of the lower flower bears a scabrid awn varying from 6 to 11 cm. long, that of the upper flower in robust forms having an awn of similar length, while in smaller forms the glume is awnless or with an awn rarely exceeding 1-2 mm. in length. When young the palea is entire, but in ripe ears it is divided longitudinally into two halves.

The caryopsis is pointed at both ends, very much laterally compressed,

and olive-yellow, with a flinty endosperm. It measures from 6 to 7·5 mm. long, 1-1·5 mm. from side to side, and 2·1-2·6 mm. from back to front. The furrow is seen as a shallow groove along the narrow edge of the grain; the radicle of the embryo is prominent, the opposite end having a "brush"

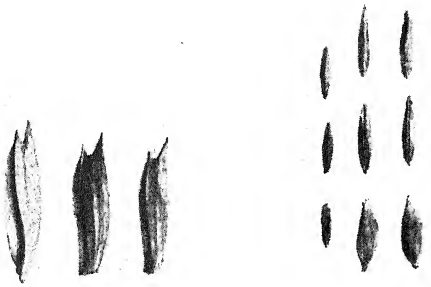


FIG. 112.—Empty glumes (× 2) and grains (front, back, and side views) of *T. aegilopoides* (nat. size).
1, var. *Larionowi*. 2, var. *boeoticum*. 3, var. *Thaoudar*.

FIG. 113.
Grains from the spikelets of one side of an ear of *T. aegilopoides*, var. *boeoticum* (nat. size).

of hairs. The weight of 100 caryopses varies from 1·0 to 1·3 grams.

T. aegilopoides may be subdivided into two sections as indicated below:

SECTION I.—Young shoots and culms erect and caespitose ("spring type"); young leaves broad (10-15 mm. across), yellowish-green.

1. Flowering glume of the lowest flower of the spikelet with a long awn (9-11 cm.), the second flowering glume usually with a short point only (2-5 mm.). var. *boeoticum*.

2. Flowering glumes of both flowers generally with equally long awns (9-10 cm.) . . . var. *Thaoudar*.

T. aegilopoides, var. **boeoticum**, mihi.

T. boeoticum, Boiss. *Diagn.* ser. i. fasc. 13, p. 69 (1853).

This is the most widely distributed European variety of *T. aegilopoides* (1, Fig. 114), being frequent in parts of southern Serbia, Bulgaria, and Greece. It is found throughout Asia Minor and has been recorded by Larionow from the Crimea, although from Vavilov's account (*Bull. App. Bot.* vol. vi. p. 691) it is probable that the Crimean form should be placed in Section II. with varieties *Pančici* and *Larionowi*, which are winter forms with narrow leaves and prostrate young shoots.

The young shoots of the forms obtained from M. Körnicke and grown at Reading are erect, the leaves pale yellowish-green, pubescent, with long white hairs sparsely distributed along the summit of the longitudinal ridges.

The ears of wild plants are 5-6 cm. long possessing 24-26 spikelets; those of cultivated specimens are often 8 or 9 cm. long with 30-32 spikelets each about 10 mm. long.

The yellowish-white glumes are usually clothed with soft inconspicuous hairs, but glabrous forms are met with: Flaksberger's var. *Zuccariorii* appears to be the pubescent form.

T. aegilopoides, var. **Thaoudar,** mihi (2, Fig. 114).

T. Thaoudar, Reuter (in Bourgeau, *Pl. Exs.*, 1860).

In 1854 Balansa collected wild strong-growing forms of *T. aegilopoides* at Balamaut Kaïvé between Smyrna and Magnesia in Asia Minor. Similar robust wild plants were discovered later in Lycia by Bourgeau (1860); near Amasia in 1889 by Bornmüller; in Northern Syria by Aaronsohn; and in 1909 in Kurdistan on the borders of Persia by Strauss.

The Turkish name for these wild forms of *Triticum* as well as for rye (*Secale cereale*) and Darnel (*Lolium temulentum*) is "Thaoudar," and Bourgeau's specimens were labelled *Triticum Thaoudar* by Reuter. I have critically examined and compared authentic specimens of all the recorded varieties of *T. aegilopoides*, and find that the Asiatic types usually have slightly broader and thicker ears with fewer spikelets than those of Serbian and Greek plants; the glumes of the former are sometimes tinged a pinkish colour, and in addition, many, though not all of them, have a long awn (9-10 cm.) on the upper as well as on the lower flowering glume.

This is the common variety of Asia Minor, although plants indistinguishable from the European variety *boeoticum* and intermediates appear with it.

The glumes, which are yellowish-white, are generally pubescent, and the outer part between the strong lateral nerve and the margin of the empty glume is sometimes broad and rounded as in cultivated *T. monococcum*.

The ears are shorter and laxer and the spikelets fewer and stouter than those of var. *boeoticum*, and in wild specimens usually 4-5 cm. long and ·8-·9 cm. wide, having 16-18 spikelets each 10-15 mm. long. When cultivated the ears attain a length of 8 or 9 cm. with 30 or more spikelets.

SECTION II.—Young shoots prostrate; culms decumbent at the base ("winter type"); young leaves narrow (4-5 mm. across) and dark green, the habit of the young plants in winter resembling that of *T. hermonis*.

1. Glumes and awns black . . . . . var. *Pančici*, mihi.
2. Glumes reddish-yellow, awns black . . var. *Larionowi*, mihi.

T. aegilopoides, var. **Pančici,** mihi.

T. monococcum, var. *Pančici*, Flaksb. *Bull. App. Botany*, Petrograd, vi. 682 (1913).

A wild black-glumed variety (4, Fig. 114) discovered by D. Larionow in 1909 near Balaklava in the Crimea, growing with vars. *boeoticum* and *Larionowi* (see below), possibly the same as *T. nigrescens*, Pančici (in *Pl. Exsicc. et litt.*, Körn. *Handb. d. Getr.* i. 109, 1885).

In the Fielding Herbarium at Oxford are four specimens of this variety

collected near Smyrna by Sherard, who was British Consul there from 1703 to 1718: they are labelled "*Hordeum distichum spica nitida arratis et glumis nigricantibus*. Comp. Tab. Bot. 38."

The following description is from plants grown at Reading, the original ears being sent me from Moscow by Dr. Vavilov:

The coleoptile is purple.

The shoots of the young plants are prostrate, the leaves narrow (4-6 mm. broad) and a dark blue-green tint. The leaves are clothed with short velvety hairs, interspersed among which are some 1-1·5 mm. long, arranged on the ridges and along the margins as in *a*, Fig. 111. The blade of the upper leaf of the straw is shorter than the sheath.

The culms at first spread outwards close to the ground, becoming erect later. They possess 4 or 5 internodes and vary much in length on the same plant, some reaching a height of 130-150 cm. (about 50-60 inches), while others are not more than 30-45 cm. (12-18 inches) long.

The upper internode is solid or hollow with thick walls and of exceptional length, being often as much as 80 cm. long.

A conspicuous muff of white reflexed hairs surrounds the nodes, below which $\frac{1}{8}$ to $\frac{1}{4}$ inch of the straw is brownish.

The ears without the awns are 9-11 cm. long and ·7-·8 cm. across the two-rowed side: they possess 28-32 spikelets and are moderately dense (D = 30-32).

The rachis is smooth, but its edges are fringed with whitish hairs 3 mm. long, and there is a frontal tuft about 3 mm. long at the base of each spikelet.

The spikelets are somewhat larger than those of var. *Larionowi*, measuring 12-14 mm. long and 4 mm. broad. They are two-flowered and usually ripen two grains in each spikelet; the lower is the smaller grain and germinates more slowly than the upper one or not at all.

The empty glumes are jet black or more or less covered with dark streaks, and the awns are black. The keel and lateral nerves are scabrid, the keel tooth about 2 mm. long and straight or bent outwards slightly.

The caryopses are small, narrow, and pointed at both ends, greenish-grey or purplish in colour with flinty endosperm. The smaller ones measure about 6 mm. long, 1·3 mm. from side to side, and 1·45 mm. from front to back, the larger ones being 7 mm. long, 1·45 mm. broad, and 1·8 mm. thick; 100 weigh from 1 to 1·2 grams.

T. aegilopoides, var. **Larionowi**, mihi.

T. monococcum, var. *Larionowi*, Flaksb. *Bull. App. Bot.*, Petrograd, vi. p. 681 (1913).

A wild form with glabrous yellowish-red glumes and black awns found in 1909 by Larionow near Balaklava in the Crimea (3, Fig. 114).

The following description is from plants grown at Reading:

The coleoptiles are purplish. The young shoots are prostrate, the foliage leaves dark blue-green, 4-5 mm. broad, with short blades and clothed with soft hairs as in var. *Pančići*.

The straws are slender, solid or hollow with thick walls, green or purplish

1 2 3 4

FIG. 114.—WILD SMALL SPELT (*T. aegilopoides*, Bal.).

1. var. *boeoticum*.
2. var. *Thaoudar*.
3. var. *Larionowi*.
4. var. *Pančici*.

with a muff of white deflexed hairs: they grow to a height of 120-150 cm., the upper internode often 60-70 cm. long.

The ears are narrow, without the awns 8-10 cm. long and ·5-·7 cm. across the two-rowed side. They possess 30-36 spikelets and are of moderate density (D = 30-32).

The rachis is smooth, its edges fringed with white hairs 2-3 mm. long; the frontal tufts of hairs at the base of each spikelet 2-3 mm. long. The spikelet is 11-13 mm. long and 3 mm. broad, two-flowered, generally producing a single ripe grain, though spikelets with two caryopses are sometimes found.

The empty glumes are glabrous, reddish-yellow in colour, the keel and strong lateral nerve scabrid; the apical tooth is about 2 mm. long and bent outwards slightly.

Both flowering glumes of the spikelet possess slender black awns, one of them 8-9 cm. long, the other 1-2 cm. long; occasionally both awns are 8-9 cm. long.

The caryopsis is laterally compressed, pointed at both ends, olive green especially the apical half, the endosperm flinty. It measures about 7 mm. long, 1·6 mm. through from side to side, and 2-2·5 mm. thick from dorsal to ventral surfaces; 100 weigh from 1·2 to 1·3 grams.

CHAPTER XI

SMALL SPELT

T. monococcum, L. *Sp. Pl.* 86 (1753).
Nivieria monococcum, Ser. *Cér. Eur.* 111, 114 (1841).
T. vulgare bidens, Alef. *Landw. Fl.* 334 (1866).
T. monococcum, B. *cereale*, Asch. u. Graeb. *Syn.* ii. 702 (1901).

SMALL Spelt, sometimes termed one-grained Wheat, St. Peter's corn, or Einkorn, is one of the most primitive of the cereals, exhibiting little differentiation from the wild *T. aegilopoides* from which it has no doubt been derived.

Its cultivation was established in prehistoric times, and evidence points to its having been one of the chief wheats grown in Mid Europe in the Neolithic period. Grains of it have been discovered in Hungary in the Stone Age deposits of Felsö-Dobzsa, the Neolithic subterranean dwellings and store-rooms of Lengyel, and in the cave deposits of Aggetelek; they have also been found in deposits of similar date in Bosnia and Denmark.

Heer states that a single ear—now lost—was obtained from the pile-dwellings, referred to the same era, at Wangen in Switzerland. Carbonised grains dug up by Schliemann at Hissarlik on the site of ancient Troy (3000–2500 B.C.) have been attributed to Small Spelt, and specimens belonging to the Bronze Age have been found at Toszeg in Hungary.

The grains of Neolithic Age are somewhat smaller than those of *T. monococcum* of the present day, resembling the caryopses of the wild *T. aegilopoides* of Serbia and Macedonia. It is possible that prehistoric man in Mid and South-Eastern Europe first selected for cultivation the wild species of this region and at the early period mentioned had made little progress with its improvement. The increased size of the grain of some of the varieties of this race at present cultivated may be the result of a long period of selection applied to the European plant; on the other hand, it is perhaps more likely that the modern forms of *T. monococcum* have been derived from the larger robust variety—*T. aegilopoides*, var. *Thaoudar* of Asia Minor.

There is no proof that *T. monococcum* was known to the ancient Egyptians, nor is there any reference to it among the Roman writers on agriculture, but τίφη mentioned by Aristotle, Theophrastus, and other early Greek authors appears to have been this cereal.

On account of its poor quality, lateness in ripening, and insignificant yield in comparison with other wheats, its cultivation is now very restricted. Nevertheless the awns and thick glumes protect it from the attacks of birds, and its power of resisting frost and rust, and the fact that it will grow without manure on poor sandy, chalky, and rocky soils where better wheats fail, adapt it to the needs of the inhabitants of barren mountainous districts.

From very early times it has been cultivated by primitive peoples in remote districts of Europe and Western Asia, and it is still grown in many parts of Spain and to a lesser extent in Switzerland, France, Italy, Germany (Würtemberg and Thuringia), Herzegovina, Greece, Macedonia, and in the Eastern Caucasus. It has also been met with in cultivation in Asia Minor, but there are no records of its occurrence in India, China, or on the continent of Africa, and it does not appear to be cultivated in Serbia or Bulgaria, of which countries its wild prototype is a native.

Small Spelt is mainly utilised in its husked state instead of barley as fodder corn for cattle and horses. In lesser amount the true grain freed from the tough glumes is used in soup and gruel in place of "pearl" barley or groats.

It has also been employed in the manufacture of beer and vinegar.

The flour obtained from it is yellow or brownish in colour, and makes a good flavoured though dark brown bread.

Both winter and spring forms are known, the former being perhaps the most frequently cultivated. In Europe the winter forms are sown in September, spring forms early in March, about 72 lbs. of husked grain per acre being needed. The crop is harvested in August or the first half of September, the yield is very variable, from 8 to 16 hectolitres per hectare (about 320-640 lbs. per acre) being obtained in poor mountainous regions; on good soils more than 80 hectolitres per hectare have been recorded.

The ears of *T. monococcum* are very brittle, and it is stated that the plant sometimes sows itself among other crops from which it is difficult to extirpate it when once established; it was reported in 1871 as a troublesome weed in cornfields round Montpellier in France.[1]

General Characters of *T. monococcum*, L.

Small Spelt is strikingly distinct from other cultivated wheats in its stiff erect habit, slender straw, and characteristic pale yellowish-green tint.

[1] *Bull. Soc. Bot. France*, p. 173 (1871).

The leaves of young plants in winter forms lie spread out on the surface of the soil, in spring forms they are more erect; the blades are narrow, from 4 to 10 mm. across, bluish-green at first, yellowish-green later, and covered with very short hairs, 50-80 μ long, on both surfaces.

Tillering is extensive, particularly so in the slow-growing winter forms.

The straw, which, according to variety, reaches a height of 60-120 cm. (2-4 feet), is smooth and thin, but tough and elastic, usually hollow in all the internodes except the basal one, which in some kinds is solid: the walls of the straw are thin.

On each there are four or five nodes, the upper ones being clothed with somewhat conspicuous deflexed hairs, those next the ground often destitute of hairs or nearly so. Just below each node the straw in the common forms is a brownish-purple colour.

In straws with four internodes the average successive lengths of the latter from below upwards were found to measure 6, 11·6, 22, and 42 cm. respectively, straws with five internodes measuring 4, 12·6, 16, 25·5, and 42·7 cm.

The combined sheath and blade of the fully developed leaves on the straws are from 25·5 to 35·5 cm. (10-14 inches) long, ·6-·7 cm. broad, the hairs on them being fewer and longer than on the young leaves of autumn and spring; the overlapping edge of the sheath is generally fringed with soft hairs.

The ligule is short and truncate, with irregular teeth; a pair of small auricles with accompanying long hairs are present at the base of the blade.

The ears are bearded, erect, laterally flattened and thin, superficially resembling those of two-rowed barley. They vary in length from 4·5 to 9 cm., having a width of 7 to 10 mm. across the two-ranked side and 3-5 mm. across the narrow face of the ear.

The spikelets are packed closely in an imbricate manner, small ears having 22-25 spikelets, the largest 45 or more; the density (D) = 50-55.

The rachis is flattened (1·2-1·5 mm. wide and ·3-·4 mm. thick) and very brittle, breaking into pieces 1·5 mm. long, to the upper end of which is attached a single spikelet. In all forms the rachis is smooth, but in some the edges are fringed with straight white hairs, especially at the point of insertion of the empty glumes, and a tuft of similar hairs is present on the rachis in front of the base of each spikelet between the glumes.

The spikelets generally possess three flowers, the upper one of which is always imperfect and sterile; in some varieties only the lower flower is fertile, while in other kinds the first and second flowers of the spikelets produce ripe grains. The terminal spikelet of the ear is very minute and barren.

Each fertile spikelet is about 10 mm. long, 4-6 mm. wide, and 3 mm. thick, the front being convex, the back flatter.

The glumes are glabrous or slightly pubescent.

The two empty glumes are shorter than the flowering glumes, boat-shaped and unsymmetrical, the halves of each right and left of the midrib differing considerably in form and width. They are strongly keeled from apex to base and usually 5-nerved, one small nerve being found on the inner narrow side of the glume close to the midrib and three others on the broad outer half, the outermost of these nerves being strong and forming a conspicuous rib.

The exposed part of the glume turned away from the rachis between the keel and the third strong nerve is thick and leathery, but its edges and the whole of the inner half nearest the rachis are thin and membranous.

The apex of the empty glume is notched in a characteristic manner, the keel terminating in an acute point or tooth 1-2 mm. long, the strong secondary nerve of the broad exposed half ending in a shorter tooth ·5-1 mm. long (Fig. 115), while a third blunter projection is seen on the narrow inner half.

The flowering glume is boat-shaped, rounded on the back, and without a keel. It is thin, white, and semi-transparent, with 9 to 11 nerves, the middle and two outermost being the strongest. The apex is divided into two short points between which arises a long straight scabrid awn of triangular section.

Well-developed awns which are only associated with the lowest flower of a spikelet vary in length from 3 to 8 cm., those in the upper part of the ear being longest. The second flowering glume, whether belonging to a barren or a fertile flower, has a short awn usually not more than 2-5 mm. long, or is awnless.

The palea is a thin membranous glume equalling the flowering glume in length, with two nerves and terminating in a blunt apex. At first it is entire, but shows a slight inward fold down the centre, along which it is torn into two separate halves when the fruit ripens ; the latter character, together with the compressed fruit, led Seringe to place Small Spelt in a separate genus, *Nivieria.*

The flowers are of the ordinary gramineous type with yellow anthers 4-4·5 mm. long and lodicules which are pubescent in the upper part.

The abortive second flower of the spikelet possesses a pistil whose stigmas are rudimentary, and three stamens, the anthers of which do not produce pollen-grains.

Anthesis begins in the upper third of the ear.

The caryopsis, which is closely invested by the glumes, is yellowish and flinty, oval and tapered at both ends, the outline of both the dorsal and

ventral surfaces being curved when the grain is viewed from the side. The radicle of the embryo projects prominently, and the opposite end of the grain is clothed with a " brush " of short hairs.

It is compressed laterally, being usually of considerably greater diameter from front to back than from side to side.

1 2 1 2 3

FIG. 115.—Empty glumes (× 2), and grains (front, back, and side views), of *T. monococcum* (nat. size).
1, var. *vulgare*;
2, 3, var. *flavescens*.

The furrow which extends to the centre of the grain is almost completely closed and only visible as a narrow groove on the ventral part of the caryopsis (Fig. 115).

The grains of different varieties measure from 7 to 8·5 mm. in length, 1·8-3 mm. in breadth from side to side, and 3-3·5 mm. from dorsal to ventral surfaces.

FIG. 116.
Grains from the spikelets of an ear of *T. monococcum* (nat. size).

The ratios length : breadth : thickness = about 100 : 26 : 43 in some varieties, in others 100 : 35·3 : 41.

The produce of the thrashed ears, *i.e.* the " husked " grain or " vesen," weighs from 40 to 50 kg. per hectolitre.

T. monococcum is a comparatively homogeneous species, the morphological diversity of the different forms being small.

The hairs on the glumes of pubescent varieties are inconspicuous and never abundant; when present they are most readily seen on the upper part of the flowering glume. In some cases the hairs are reduced or disappear altogether under good cultivation.

Both winter and spring forms are known, the former having narrower leaves, shorter culms, and smaller ears than the latter; they also ripen later than the spring varieties.

In most wheats the length of the axis and number of spikelets in the ear is subject to little variation, but in this race these characters are very extensively influenced by the fertility of the soil, the date of sowing, and by climatic conditions.

On poor soils the ears are often not more than 3 or 4 cm. long, but when grown on good soils the ears may reach a length of 9 cm. ($3\frac{1}{2}$ inches) or more and possess 40 or 50 spikelets.

In general facies *T. monococcum* closely resembles the wild *T. aegilopoides*; it differs from the prototype in having somewhat broader, closer-set, and larger ears, and grains of slightly larger size; its awns are, however, shorter, being usually not more than 4-8 cm. long, while those of the wild species reach a length of 10-11 cm.

The leaves are covered with very short hairs (*b*, Fig. 111), there being no long ones on the ridges as in *T. aegilopoides*. The leaf-sheaths, auricles, and rachis of the ear in the cultivated plant are much less hairy, and the empty glumes broader with rounded and more membranous margins than those of *T. aegilopoides*. The terminal keel tooth of the empty glume of the latter is generally bent outwards; in most varieties of *T. monococcum* it is either straight or curved slightly inwards.

VARIETIES OF *T. monococcum*, L.

1. Glumes pale reddish-yellow or brownish, glabrous, shining. var. *vulgare*, Körn.
2. Glumes pale yellow, scabrid, dull . . . var. *flavescens,* Körn.
3. Glumes reddish-brown or brownish-yellow, pubescent, dull. var. *Hornemanni*, Körn.

Glumes pale reddish-yellow or brownish, glabrous, shining.

T. monococcum, var. **vulgare**, Körn. *Handb. d. Getr.* i. 112 (1885).

This variety (2, Fig. 117) is a winter form of slow growth, but often ripens grain at Reading in the same season, even when sown as late as the beginning of March.

When sown in autumn the ears appear in the last week of the following June or the first week in July.

The plants tiller extensively, producing 10-15 straws per plant when the grains are sown 6 inches apart in rows 6 inches asunder.

The coleoptile is purple, the young foliage leaves narrow, about 4 mm. across, bluish-green, and lying close to the surface of the ground in winter; the fully developed culm leaves are 6 to 8 mm. across, of a yellowish-green tint. The leaf-sheaths are generally smooth, the lower ones and the fringed auricles usually pinkish.

The straw is very short, from 65 to 75 cm. (about 25-30 inches) in height, slender, elastic, and hollow, with thin walls, the nodes covered with fine more or less adpressed and deflexed hairs.

The ears are thin, smooth, and reddish-yellow, with more or less polished surfaces, the keel and veins of the glumes being non-scabrid or nearly so; they average 5-6 cm. in length, about 8 mm. in width, and 3-4 mm. across the face of the spikelets, each of which usually contains only one small compressed caryopsis. D = about 54.

Only the flowering glume of the lower flower has an awn, 3-8 cm. long, that of the second flower being awnless.

The produce of the thrashed ears, *i.e.* the husked grain or "Vesen," consists of about 80 per cent of caryopses and 20 per cent of chaff (pieces of rachis and glumes). From 450 to 480 caryopses weigh 10 grams.

The caryopses are yellowish and flinty, flattened from side to side; they measure about 7 mm. long, 1·8-2 mm. through from side to side, and 3 mm. from front to back.

The average ratio of length, breadth, and thickness = 100 : 27·1 : 42·8 respectively.

Glumes pale yellow, scabrid, dull.

T. monococcum, var. **flavescens,** Körn. *Handb. d. Getr.* i. 112 (1885).

T. monococcum, a. *alba spica glaberrima*, Lam. *Enc.* ii. 560 (1786).

The commonest representative of this variety (3, Fig. 117) is known as *Engrain double* in France, into which country Heuzé says it was introduced from Spain about 1850. It is a spring form with caespitose young shoots. The plants ripen from 15 to 20 days earlier than the preceding variety when both are sown at the same time either in autumn or spring. The coleoptile is colourless and the young foliage leaves much broader than those of other varieties, being from 10 to 12 mm. wide. The auricles are fringed with a few long hairs and, like the leaf-sheaths, usually pale green; the leaf-sheaths have long hairs sparsely distributed over their surfaces. The straw is strong and hollow, with thick pithy walls and of medium height, reaching a length of 100-115 cm. (40-45 inches) or more. On the nodes are spreading deflexed hairs.

The ears are pale straw colour, usually 5-6 cm. long, less densely packed on the rachis and thicker than those of var. *vulgare*. D = about 50.

The spikelets are broad, 4·5-5 mm. across, and in some ears many of them contain two well-developed caryopses. The "Vesen" have a less proportion of "husk" than those of the Common Small Spelt, averaging 16 per cent husk to 84 per cent of true grain.

The coarse empty glumes have characteristic rough dull surfaces, on which are minute papillae; the keel and outer nerves are strong and scabrid; their apical teeth not so acute as in other varieties.

The flowering glume of the second flower possesses a short awn 2-5 mm. long, that of the first or lower flower having an awn 3-6 cm. long.

The caryopses are longer and broader than those of var. *vulgare*. The ventral surface of the grain is broader and flatter and the furrow more easily seen than in those of the previously mentioned varieties. They measure 8-8·5 mm. in length, 2·5-3 mm. in width, and 3-3·5 mm. from front to back; from 340 to 350 weigh 10 grams.

The average ratio of length : breadth : thickness = 100 : 33·3 : 39·3.

Körnicke's variety *laetissimum* appears to be merely a small pale-eared form of var. *flavescens*.

I 2 3

FIG. 117.—SMALL SPELT (*T. monococcum*, L.).

1. var. *Hornemanni*. 2. var. *vulgare*.
3. var. *flavescens* (Engrain Double).

Glumes pale reddish-yellow or brownish, pubescent, dull.

T. monococcum, var. **Hornemanni**, Körn. *Handb. d. Getr.* i. 112 (1885).
T. Horneman, Clemente (in Herrera, *Agric. gen.* i. 3, 1818).
T. monococcum, b. *spica pallide rubra pubescente*, Lam. *Encyclop.* ii. 560 (1786).

This is the largest and most commonly cultivated variety of *T. monococcum* (1, Fig. 117), ripening at Reading about the middle of June, resembling in this respect var. *flavescens*.

It is grown in small quantity in Switzerland and Spain and the Eastern Caucasus (Tersk Government), and was formerly cultivated by Tatars in the Crimea.

The commonest representative of this variety is a spring form with caespitose young shoots, and stout straw of medium height (110-120 cm.). The leaf-blades are about 10 mm. across and yellowish-green.

The ears are pale reddish brown from 6 to 10 cm. long, 10 to 11 mm. across the 2-ranked side and 4 to 5 mm. across the narrow face. The number of spikelets 25-40. D=40-50.

The spikelets are 11-12 mm. long, 5 mm. broad, usually ripening one grain in each, although spikelets with two fully developed caryopses are frequent.

The glumes near the tips are clothed with short inconspicuous hairs and the flowering glume of the lower flower bears an awn about 9 cm. long, that of the second upper flower having only a short awn 3-6 mm. long.

The caryopses are 8-9 mm. long.

CHAPTER XII

WILD EMMER

T. **dicoccoides**, Körn. *in litt. ex* Schweinf. in *Ber. d. Deutsch. Bot. Ges.* 309 (1908).

T. vulgare, Vill., var. *dicoccoides*, Körn. *Verh. des naturhist. Vereins d. Pr. Rheinl.*, Jahrg. 46, Bonn (1889).

T. hermonis, Cook. *Bureau of Pl. Ind.* (*U.S.A.*) *Bull.* No. 274, 13, 52 (1913).

In 1873 Körnicke discovered in the National Herbarium at Vienna a portion of an ear of a species of *Triticum* among specimens of *Hordeum spontaneum* collected in 1855 by Theodor Kotschy at Rasheyya on the north-western side of Mount Hermon in Syria. In 1899 he referred to the plant at a meeting of the Niederrheinischen Gesellschaft für Natur- und Heilkunde, and according to the report of the meeting he named it *T. vulgare*, Vill., var. *dicoccoides*, considering it closely allied to Emmer and the prototype of most of the cultivated wheats.

The plant was rediscovered first at Rosh Pinar at the foot of Jebel Safed in Syria by Aaronsohn in 1906 and later at Rasheyya and other parts of Mount Hermon as well as on the plateau of Es-Salt east of the Jordan valley. Specimens were also collected in 1910 by Theodor Strauss in the mountainous region of Western Persia near Kerind, between Kermanshah and Bagdad.

T. dicoccoides grows in the crevices of limestone rocks in dry situations from 300 to 500 feet below to over 6000 feet above the level of the Mediterranean, and is generally associated with *Hordeum spontaneum* and often with forms of *Triticum aegilopoides*.

The reports of Aaronsohn, Cook, and others who have observed *T. dicoccoides* in its native habitat leave no doubt that it is truly wild, and different from any kind of wheat at present cultivated in Palestine.

For some time I have grown it from ears obtained from El Hadr and the eastern slopes of Mount Hermon. I have also examined specimens collected by Strauss in Western Persia and others from various parts of Syria.

The plants in their native habitat exhibit great diversity in the form of the glumes, the size and prominence of the keel and secondary teeth, and

in the colour and pubescence of the glumes and rachis (Fig. 119). There is no doubt that some of these forms are hybrids of *T. dicoccoides* with the cultivated wheats *T. durum* and *T. vulgare*, and probably with the wild *T. aegilopoides* which is often found growing with it. However, investigation of the pure lines established at Reading from ears collected on Mount Hermon indicate that *T. dicoccoides* is a good species. The larger size of the ear, the form and size of the grain, and the character of the pubescence of the leaves separate it from *T. aegilopoides*, while the exceptionally easy disarticulation of the ear, the length and form of the spikelets, the striking abundance of hair on the rachis, and the shape and size of the grain distinguish it from cultivated Emmer (*T. dicoccum*), to which wheat it has the closest affinity.

T. dicoccoides is an early species coming into ear at Reading about the last week of May when sown in October or November, in this and other respects very closely resembling the cultivated varieties of *T. dicoccum* from India and Abyssinia.

General Characters of *T. dicoccoides*, Körn.

The coleoptiles are generally deep purple, though in some cases they are colourless or pale green. They are remarkable in possessing four vascular bundles like those of the Indian and Abyssinian forms of *T. dicoccum*, which I have no doubt have been derived from this wild species.

The leaves of the young plant are narrow, the first being 2·5-3 mm., the succeeding ones about 4 mm. broad, somewhat thick, bluish green in colour, the margins inclined to curve inwards, and the surface clothed with soft velvety hairs similar in character and arrangement to those of *T. dicoccum* and *T. turgidum*, and without the specially long hairs which are seen on the summits of the ridges of the leaves in *T. aegilopoides* (Fig. 118).

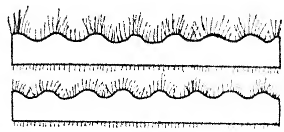


Fig. 118. — Diagrammatic transverse sections of young leaves of *T. dicoccoides*, *T. dicoccum*, *T. orientale*.

The plant in its early stages of growth resembles couch grass (*Agropyrum repens*) in colour and general appearance, and from autumn to late in spring its shoots and leaves are prostrate, lying quite close to the surface of the soil.

The culm leaves are somewhat rigid and narrow, 4-6 mm. across, with well-defined, longitudinal, hairy ridges on the upper surface ; the auricles are long, often purple, and the sheaths are frequently more or less tinged with purple.

The sheaths in some forms are quite glabrous, or with a fringe of hairs on the outer edge ; in others they are covered with hairs 1 mm. or more long. The thickened nodal portion in many forms is from ·8 to 1 cm. long and clothed with deflexed hairs as in *T. monococcum*.

The plants tiller freely and the first few straws expand to full length a week or ten days before the rest, which are much shorter and remain green some time after the first ears are ripe. At the time of harvest each plant exhibits ears dead ripe with the terminal spikelets shed, others just ripe, some green, as well as a few still enclosed in their leaf-sheaths.

The culms are slender but strong, from 65 to 100 cm. long (about 26-40 inches), with 4 or 5 internodes above ground, the upper one often reaching a length of 50-60 cm. (about 20-30 inches). In some varieties they are hollow throughout, in others the upper internode is solid or nearly so.

Before the ears escape from the upper leaf-sheaths the shoots with the culms enclosed lie close to the surface of the soil, but towards the middle of May at Reading the shoots rise rapidly, becoming more or less vertical in about a week; later they incline again, the ripe ears often touching the ground.

The bases of the culms of mature plants curve away from each other in a characteristic decumbent manner, the plants appearing to occupy a considerable area of ground.

The ears are bearded, stiff, and laterally compressed, measuring 4 to 6 mm. across the face of the spikelets, and 7 to 9 mm. across the two-ranked side of the ear. They vary in length from 8 to 10 cm. without the awns and consist of 12 to 17 spikelets; D = 17-20.

The surface of the flattened rachis is smooth and shining, but along its edge is a conspicuous fringe of white, yellow, or dark-brown hairs which are often 5 mm. long, and visible when the ear is viewed from the side; in front of the base of each spikelet is a tuft of similar hairs which sometimes extend across the rachis from one margin to the other at that point.

The lateral spikelets usually have three flowers, the first only, or first and second of which are fertile; they are from 15 to 20 mm. long, 5 to 6 mm. broad, and 3·5 mm. thick.

The terminal spikelet is usually, though not always, sterile, and its glumes are generally well developed.

The lateral empty glumes, which may be yellowish or pinkish white, red, uniformly black, striped along the margins or spotted irregularly with dark brown, are from 10 to 15 mm. long, the outer half 2·4 to 3 mm. across, the inner half about 1 mm. broad. They are coriaceous and rigid, usually 5-7 nerved, long and narrow, with a scabrid keel and either glabrous or covered with silky hair. The apical tooth varies much in length and form; in some cases it is bluntish, in others acute and 1-5 mm. long; it is usually straight but may curve slightly inwards or outwards (Fig. 119).

The strongest nerve on the broad exposed half of the glume converges towards the base of the apical tooth, where it ends in a secondary tooth which in some specimens is ·5 mm. long, in others very short.

The empty glumes of the apical spikelet are almost symmetrical with two strong nerves which terminate in blunt points.

The flowering glume is boat-shaped, 10-15 mm. long and 5-7 mm. broad, rounded on the back, mostly with 9 nerves, membranous, in colour like the empty glume, and slightly divided near the apex, the free apical points being about 1 mm. long. It possesses a very scabrid and slightly dorsal awn. Awns are always present on the two lowest flowering glumes of the spikelet, and are often of nearly equal dimensions, generally 10-12 cm. long, but in some cases reaching a length of 18 cm. or more; occasionally the awn of the upper of these two flowers is only about half the length of that of the lower one, small ears then resembling some forms of *T. aegilopoides*.

The palea, which is about as long as the flowering glume, is smooth

FIG. 119.—Empty glumes of forms of *T. dicoccoides* (× 2).

and membranous, divided at the tip, two-nerved and bicarinate, the two ciliate keels often slightly scabrid near the tip.

The flowers resemble those of other wheats and generally have purple anthers, though in a few forms the latter are yellow.

Anthesis first occurs in the spikelets nearer the apex of the ear than is the case among cultivated wheats.

The caryopses are reddish, long and narrow, pointed at both ends and compressed laterally, the dorsal side forming a ridge; the ventral furrow is a narrow V-shaped groove, the flanks right and left of the furrow angular.

In profile the ventral side of the grain is a straight line, thus differing from *T. aegilopoides*, whose outline is strongly curved on the ventral as well as the dorsal side.

At the apex of the grain is a tufted "brush" of whitish hairs 1-1·5 mm. long (Fig. 120).

The endosperm is flinty.

When two caryopses are present in a single spikelet the one produced by the lower flower is the smaller.

The grains of the small forms which I consider typical *T. dicoccoides* are about 9 mm. long, 1·7 mm. broad, and 1·85 mm. thick, the ratios length : breadth : thickness = about 100 : 19 : 20·5 ; 100 grains weigh from 2·2 to 2·8 gr. Those of the form called "large seeded" by Cook are among the longest of all wheat grains, equalling in this respect those of *T. polonicum* ; they measure 11-12 mm. long, 2·9 mm. broad, and 2·7 mm. thick, the ratios length : breadth : thickness = about 100 : 25 : 23 ; 100 grains weigh from 5 to 7 gr.

FIG. 120.—Grains, front, of *T. dicoccoides* ; front, back, and side views (nat. size).

I am of the opinion that most of these "large-seeded" forms are of hybrid origin, and contain a trace of *T. durum*.

The rachis of the ripe ear becomes disarticulated at its joints on the slightest shake, the spikelets near the apex becoming detached first, the others breaking off in orderly succession towards the base ; the basal spikelets are frequently green and unripe when the apical spikelets begin to fall. The short internodes of the rachis form beaks at the base of the detached spikelets.

Each flattened internodal beak is from 4 to 5 mm. long, somewhat convex on one side and correspondingly concave on the other, the base or free end slightly curved to one side, so that the plane of the disarticulation-scar is almost parallel to the flat side of the rachis ; the scar is shaped like a narrow segment of a circle. The detached spikelets after falling to the ground creep into crevices and bury themselves in the soil, the hairs on the rachis and the scabrid awns allowing free motion in a forward direction, but effectually preventing any backward movement.

FIG. 121.—Grains from the spikelets of one side of an ear of *T. dicoccoides* (nat. size).

In the small-grained forms where two caryopses are present in a spikelet the upper grain germinates very soon after sowing, but the lower one remains dormant for a time or refuses to grow at all ; this difference

FIG. 122.—WILD EMMER (*T. dicoccoides*, Körn.).

1. var. *Kotschyanum*.
2. var. *fulvovillosum*.
3. var. *spontaneonigrum*.
4. var. *Aaronsohni*.

is observed even when the germinating capacity is tested on grains free from the glumes.

In the large-grained forms both grains germinate at the same time when freed from the glumes.

VARIETIES OF *T. dicoccoides*, Körn.

1. Glumes white, glabrous	var. *Kotschyanum*, mihi.
2. Glumes white, pubescent	var. *fulvovillosum*, mihi.
3. Glumes reddish, glabrous	var. *Aaronsohni*, mihi.
4. Glumes black or striped, glabrous . .	var. *spontaneonigrum*, mihi.
5. Glumes black or striped, pubescent . .	var. *spontaneovillosum*, mihi.

Glumes white, glabrous.

T. dicoccoides, var. **Kotschyanum**, mihi (Figs. 122, 123).

This is one of the commonest varieties on Mount Hermon. It possesses glabrous yellowish-white glumes, a conspicuous frontal tuft, and long hairs on the edges of the rachis. The ears are 6-8 cm. long and have 12-15 spikelets.

T. dicoccoides forma Straussiana, Schulz (*Ber. d. Deutsch. Bot. Ges.* xxx. 226 (1913), is the western Persian representative of this variety; *forma Kotschyana*, Schulz (!), has a less hairy rachis and is probably a cross or a form produced by cultivation.

Glumes white, pubescent.

T. dicoccoides, var. **fulvovillosum**, mihi (Figs. 122, 123).

A common variety received from Mount Hermon. It is similar to var. *Kotschyanum*, but with soft white hairs on the glumes and long yellowish or orange-brown hairs on the rachis. The apical tooth of the empty glume is generally short and blunt.

I received from Dr. M. Körnicke a very late form which must be classed with this variety (4, Fig. 123). It has large coarse spikelets 1·5-1·8 cm. long, the outer glumes clothed with long silvery hairs and terminated by a curved tooth 4·5 mm. long (9, Fig. 119); the awns are exceptionally stout and 18-20 cm. long. Figured also by Aaronsohn (*Bur. Pl. Ind. Bull.*, No. 180, Pl. vii. Fig. 1). It is probably a hybrid of *T. dicoccoides* and *T. durum*.

Glumes reddish, glabrous.

T. dicoccoides, var. **Aaronsohni**, mihi (4, Fig. 122).

T. dicoccum, var. *Aaronsohni*, Flaksb. *Bull. App. Bot.*, Petrograd, vii. 767 (1914).

This variety resembles var. *Kotschyanum*, but its glumes are pale brownish or pinkish-red.

A common large-seeded form of it from El Hadr very closely resembles the cultivated Emmers (*T. dicoccum*) of Abyssinia and India in its erect straw, pale yellowish-green leaves, comparatively glabrous rachis, and early ripening period.

Glumes black or striped, glabrous.

T. dicoccoides, var. **spontaneonigrum**, mihi (3, Fig. 122).

T. dicoccum, var. *spontaneonigrum*, Flaksb. *Bull. App. Bot.*, Petrograd, vii. 768 (1914).

A frequently occurring variety with smooth shining glumes, which are uniformly black or striped, with dark brown lines or spots on a yellowish or reddish-white ground.

Usually the hairs on the rachis are pale yellow or white, but sometimes the black or deep brown pigment present in the glumes is also found in many of these hairs.

Glumes black or striped, pubescent.

T. dicoccoides, var. **spontaneovillosum**, mihi.

T. dicoccum, var. *spontaneovillosum*, Flaksb. *Bull. App. Bot.*, Petrograd, vii. 768 (1914).

This differs only from the previous one in having villose or pubescent glumes.

All the varieties of *T. dicoccoides* are found in the neighbourhood of Mount Hermon; many of them are found also in other parts of Syria and Palestine, and var. *Kotschyanum* extends to Western Persia, but the distribution of the different varieties is not yet fully known.

As already mentioned, *T. dicoccoides* is a well-defined species, commonly self-fertilised, but at the time of anthesis its glumes remain widely separated, with the stigmas exposed for several hours during the day in bright weather, and crossing also occurs among the several varieties.

In addition natural hybridisation certainly takes place between this species and forms of the cultivated wheats *T. durum* and *T. vulgare*; crossing probably occurs with *T. aegilopoides* and possibly also with *Aegilops ovata*.

To such hybridisation is doubtless due the numerous intermediate and extraordinarily diverse forms met with in its native habitat, and among the progeny of plants cultivated at Reading and elsewhere.

Aegilops ovata is a common indigenous species in the wild wheat region of Palestine, and Cook records the finding of spikelets intermediate between this species and *T. dicoccoides*, suggestive of a natural hybrid between these two plants. I have not seen these.

Triticum aegilopoides, var. *Thaoudar*, is a common wild species, often associated with *T. dicoccoides*, and Aaronsohn mentions the occurrence of forms morphologically intermediate between the two. I have also observed small plants of *T. dicoccoides* which in glume characters suggest a relationship with *T. aegilopoides*. Schulz considers that these are hybrids of the two species, but without further knowledge of the normal

1 2 3 4

FIG. 123.—WILD EMMER (*T. dicoccoides*, Körn.).

1. var. *Kotschyanum*. 2-4. var. *fulvovillosum*.

variation of the plants and the experimental production and cultivation of the hybrid the matter must remain unsettled.

While the majority of ears collected on Mount Hermon, when grown at Reading, have given forms of *T. dicoccoides* with constant characters, many of them have produced a mixed progeny of typical *dicoccoides* and a small number of *vulgare* and *durum*-like forms, most of which in the first season are either completely sterile or produce only two or three fertile grains in an ear.

During the last ten years I have grown *T. dicoccoides* and found that these natural hybrids are produced in bright, hot seasons. Apparently typical ears of *T. dicoccoides* sometimes give rise to offspring like themselves, together with forms of *T. durum* and *T. vulgare* and *T. Spelta*; in such cases one of the grains of a spikelet often produces the typical wild wheat, while the other grain of the same spikelet gives rise to one or other of the strikingly different cultivated wheats.

CHAPTER XIII

EMMER

Triticum dicoccum, Schübler. *Char. et Descr. cerealium in Hort. Tub.* 29 (1818).

*T. Spelta * dicoccon*, Schrank. *Baier. Fl.* i. 389 (1789).
T. Spelta, Host. *Gram. Austr.* iii. 21, t. 30 (1805), (*non* Linn.).
T. farrum, Bayle-Barelle. *Mon. de Cer.* 50, t. 4, Figs. 1 and 2 (1809).
T. amyleum, Seringe. *Mélanges botaniques*, 124 (1818).
T. Zea, Wagini. *Anb. d. Getreid.* 33 (1819).
Spelta amylea, Seringe. *Cér. Eur.* 76 (114), (1841).
T. vulgare dicoccum, Alef. *Landw. Fl.* 331 (1866).
T. dicoccum, Körn. *Handb. d. Getr.* i. 81 (1885).
T. sativum dicoccum, Hack. *Nat. Pfl.* ii. 2, 81, 84 (1887).

The word Emmer is found in old glossaries of the eighth-thirteenth centuries as Amer, Amar, and Emmer. Its derivation is obscure, but it is probably of Celtic origin, for in a glossary to Prudentius it is stated that "far is a genus of corn which is called 'emerum' by the Celts of Gaul."

In Germany in mediaeval times this cereal was termed Amelkorn or Ammelkorn, a name which Bock (1539) and Fuchs (1543) say was given to it because Amylon or Amylum (starch) was prepared from it; its French name Amidonnier is similarly connected with Amylon or Amylum.

Emmer is one of the most ancient cultivated cereals. A beardless ear of it is described by Heer from the Neolithic pile-dwellings at Wangen (Switzerland), and Schulz states that remains of it from the Neolithic period have also been obtained in Denmark, Germany (Bruchsal and Heidelberg), and Bohemia (Kl. Czernosek).

Portions of ears were found in prehistoric pile-dwellings at Ripač near Bihač in Bosnia, and grains attributed to this species by Wittmack and Buschan were found among the vegetable remains from prehistoric pile-dwellings of the Bronze Age at Auvernier and Peterinsel (Switzerland). Fragments of carved models of ears (natural size) in ivory and wood from the tomb of King Zer-Ta (third king of the Ist Dynasty 5400 B.C.) are good representations of ears of *T. dicoccum*, although described as ears of

" bearded barley " in the memoirs of the Egypt Exploration Fund (21st *Memoir*, 1901, Plates v. Fig. 16 ; vi. Fig. 17 ; xxxiv. Figs. 82 and 83).

Portions of ears, spikelets, and grain exhumed from the foundations of the tomb of King Sashu-Re of the Vth Dynasty (3000–4000 B.C.) have been identified and described by Schulz. Excellent specimens of spikelets (Fig. 124) with enclosed grain and portions of culms were given to me by Sir Ernest Budge, who found them in a box in a tomb of the XVIIIth Dynasty (about 1400 B.C.).

Ears and grain were also discovered in a tomb at Gebelen (XIth-XXIst Dynasty), and other examples have been obtained from graves of the XIIth Dynasty.

Hrozny states that, next to barley, Emmer was the chief cereal culti-

FIG. 124.—Spikelets and grain of *T. dicoccum*. Upper row recent ; lower row, ancient Egyptian specimens (1400 B.C.)

vated in ancient Babylon (4000 B.C.) down to the beginning of Persian rule over the country.

There is no doubt that Emmer was widely grown by prehistoric man in various parts of Europe and Asia, and was one of the chief cereals cultivated in Egypt from the earliest times to the Graeco-Roman period and later, when it appears to have been largely supplanted by macaroni and ordinary bread wheats.

The *bote* of the Ancient Egyptians, ὄλυρα (olura) and ζέα or ζειά (zea or zeia) of early Greek authors, and the *far* of ancient Roman writers on agriculture, were forms of this " spelt " wheat, and not *T. Spelta*, with which it is so often confused by translators of the Classics.

Although an important cereal in the earliest times, its cultivation is now restricted to comparatively small dimensions, and is of little moment

in comparison with the area devoted to ordinary bread and macaroni wheats. In districts in South Germany in which *T. Spelta* is extensively grown small areas are devoted to *T. dicoccum*, in place of barley as a spring-sown cereal, and a small amount is raised in Switzerland, France, Italy, Serbia, Spain, and the United States. In some of these countries a little of the free grain is utilised for human food, but the greater portion grown there is fed in the husk to horses and other stock in place of oats and barley. It is cultivated on a much larger scale for human food in Russia and Abyssinia, and is also grown for the same purpose in moderate quantity in India, especially on irrigated land in Madras, Mysore, Bombay, Berar, and the Central Provinces.

It was apparently grown in Egypt in small quantities about the beginning of the nineteenth century, but is not found there in cultivation now. There are reports of it as a cultivated crop among the Kurds in the province of Luristan in Western Persia (Haussknecht, 1868) and in Yeman, Arabia (Glaser, 1891).

I have no records of its cultivation at the present day in Asiatic Turkey nor in China.

Emmer will grow on soils which are too light to yield a good crop of *T. Spelta*. The method of cultivation adopted for the latter is applicable, however, to Emmer (see p. 326). It is more or less immune to rust fungi and suited to warm, dry climates ; the majority of forms are rapid-growing spring varieties, with erect caespitose habit and little power of resisting frost.

One late variety with black glumes, however, is more hardy, and is a typical winter form whose young shoots lie close to the surface of the ground.

The yield per acre varies between twenty-five and fifty bushels of " spelt " grain.

The grains are starchy and the flour obtained from them is especially white and highly esteemed for the manufacture of the finest pastry and cakes. As an addition to soup, they are superior to " pearl " barley or Dinkel grain. A fine starch can be prepared from the flour.

General Characters of *T. dicoccum*, Schübl.

The young plants of all varieties except Black Winter Emmer have an erect habit, with comparatively broad leaves, measuring 7-8 mm. across.

The wheats belonging to this race fall into two groups, viz. :

1. Indo-Abyssinian Emmers ; all early forms, with four- to six-nerved coleoptiles, yellowish-green leaves, short straw, ears with brittle or tough rachis.
2. European Emmers, later in growth, with two-nerved coleoptiles, glaucous leaves, taller straw, and fragile rachis.

In the European Emmers the leaf-blades are covered with soft hairs (Fig. 118), and are bluish-green in tint with large fringed auricles. The Indian and Abyssinian forms possess paler yellowish-green culm leaves, which have fewer and shorter hairs on the ridges, and the auricles are frequently quite glabrous.

The leaf-sheaths and auricles of most Emmers are pinkish. The plants tiller moderately. The straw is strong and somewhat slender; in some varieties it is hollow, in others the upper internode is solid. Most European forms reach a height of 100-125 cm. (about 39-50 inches); the Indian and Abyssinian forms are rarely taller than 55-65 cm. (about 22-26 inches); the full-grown culm leaves have a breadth of about 16 mm.

The ears, which are white, red, or black, are usually bearded, erect, and laterally compressed, although in a few kinds the cross section of the ear is almost square. Those of different varieties vary in length from 5 or 6 cm. to over 10 cm., with fifteen to thirty or more spikelets; the density varies between wide limits (D = 24-40).

The rachis is flattened and smooth, more or less hairy along the margins with a tuft in front between the empty glumes; each individual segment is narrow at the base, widening upwards in some cases to about twice the breadth at the top. In some forms it is fragile and the grains firmly enclosed in the glumes; in others of the Indo-Abyssinian sub-race the rachis is tough and not so readily disarticulated, and in these the grains are more loosely invested by the chaff.

In the "spelt" forms the rachis becomes disarticulated at the narrowest basal end of each internode, each separate spikelet carrying with it the internodal portion immediately below it (Fig. 124).

The spikelets, which are more or less closely imbricate on the rachis, are oval, from 5 mm. to 8 mm. across, and twice as long, containing three or four flowers, the two lower ones usually producing grain, those above being rudimentary.

The empty glumes are oval and boat-shaped, narrow towards the apex, seven-nerved, with a prominent keel running from base to apex and ending in a straight or curved tooth, which varies in length and form in different varieties: in one form the empty glume has a long awn (Fig. 125). The outer half is somewhat flat and about twice as wide as the inner half of the glume; upon it is a lateral nerve, which divides the outer half almost equally, and ends near the base of the apical tooth, sometimes in a short point.

The flowering glumes are boat-shaped, rounded on the back, with nine to eleven nerves, but without a keel; they are usually terminated by scabrid three-angled awns from 5 to 14 cm. in length. The awn of the lowest flowering glume of a spikelet is longest, that of the second slightly

shorter, a very short one or none at all being found on the glumes enclosing abortive flowers.

The palea is equal to, or slightly longer than, the flowering glume, ovate-lanceolate, with a narrow bifid apex, and an inward fold between its two keels, the latter ciliate, especially near their tips. The two margins

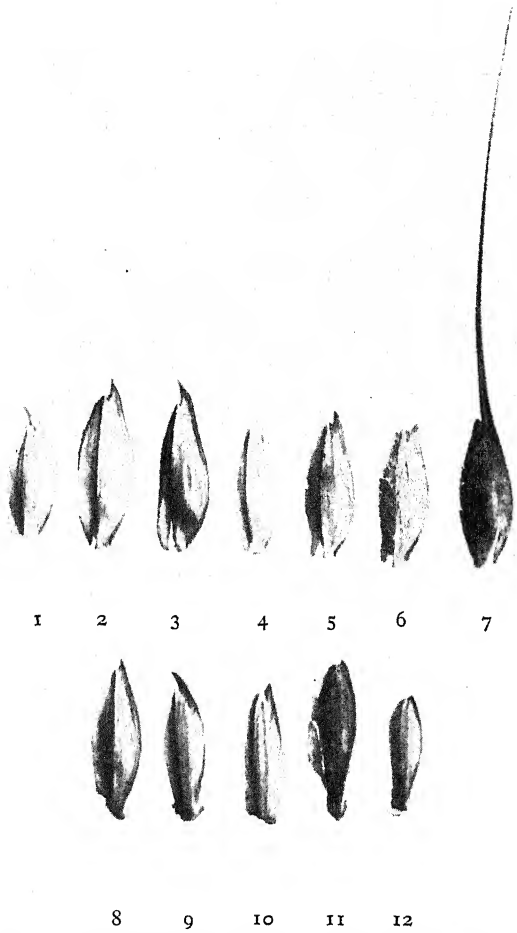


FIG. 125.—Empty glumes of Emmer (*T. dicoccum*) (× 2).

of the palea, which curve inward round the grain, are transparent, with a single nerve running through each.

The caryopses of the "spelt" forms are firmly enclosed by the glumes, and do not thrash out as naked grains ; in other forms the grain is readily separated from the chaff on thrashing.

Two, or occasionally three, are present in each spikelet.

The colour of the grain is chiefly white, yellowish, or red as in other races, but in recently harvested grains of the Abyssinian varieties *Arraseita* and *Schimperi* it is a deep purple tint, the anthocyan pigment being present in the "chlorophyll layer" of the pericarp, and to a lesser extent in some of the adjacent parenchyma.

The grains are comparatively narrow and pointed at both ends and more or less laterally compressed, with a flattish or hollowed ventral surface and a narrow furrow (Figs. 126, 127); each has a conspicuous "brush" of hairs. A cross section of the grain is somewhat triangular, with fairly distinct basal angles. In some varieties the endosperm is flinty, in others mealy.

Fig. 126.—Grains of Emmer (*T. dicoccum*). Front, back, and side views (nat. size).

Fig. 127.—Grains of the spikelets of one side of an ear of Emmer (*T. dicoccum*) (nat. size).

Well-developed grains measure from 7·2 to 9 mm. in length, 2·85 to 3·4 mm. in width, and 2·6 to 3·1 mm. through from front to back. They are slightly more compressed laterally than the grains of Dinkel or Large Spelt (*T. Spelta*); the average ratio of length, breadth, and thickness = 100 : 37·7 : 34·1.

The produce of the thrashed ear of the "spelt" forms, *i.e.* the "husked" grain or "Vesen," consists of 73 to 75 per cent of caryopses and 21 to 25 per cent of chaff (glumes and pieces of the rachis), and weighs from 40 to 49 kg. per hectolitre.

VARIETIES OF *T. dicoccum*, Schübl.

Group I.—Indo-Abyssinian Emmers. Coleoptile 4- (3-6) nerved.

Section A.—*Speltae*. Rachis fragile.

1. *Ears bearded*—
   (1) Glumes white, glabrous; grain red . . . . . var. *Ajar*, mihi

Section B.—*Tenaces*. Rachis tough.

1. *Ears bearded*—
   (1) Glumes white, glabrous; awns white; grain red . . . . var. *uncinatum*, mihi.
   (2) Glumes white, glabrous; awns black; grain red . . . . var. *pseudo-uncinatum*, mihi.
   (3) Glumes white, glabrous; grain purple . . var. *Arraseita*, mihi.
   (4) Glumes white, pubescent; grain white . . var. *tomentosum*, mihi.
   (5) Glumes red, glabrous; grain red . . . var. *rufescens*, mihi.
   (6) Glumes red, glabrous; grain purple . . var. *Schimperi*, mihi.
   (7) Glumes dark brown or mottled, pubescent . var. *persicum*, mihi.

Group II.—European Emmers. Coleoptile 2-nerved.

1. *Ears bearded*—
   (1) Glumes white, glabrous.
      i. Awns short . . . . var. *tricoccum*, Körn.
      ii. Awns long.
         a. Ears simple * narrow . . . . var. *farrum*, Körn.
         ** broad and dense . . var. *liguliforme*, Körn.
         b. Ears branched . . . . . var. *albiramosum*, Körn.
   (2) Glumes white, pubescent.
      i. Awns short.
         a. Ears simple . . . . . . var. *submajus*, Körn.
         b. Ears branched . . . . . . var. *Metzgeri*, Körn.
      ii. Awns long.
         a. Narrow lax ears.
            * Awns straight . . . . . var. *semicanum*, Körn.
            ** Awns bent, often black . . . var. *flexuosum*, Körn.
         b. Broad dense ears; black awns . . var. *majus*, Körn.
   (3) Glumes red, glabrous.
      i. Awns short.
         a. Ears simple . . . . . . var. *Fuchsii*, Körn.
         b. Ears with double spikelets . . . var. *Dodonaei*, Körn.
         c. Ears branched . . . . . . var. *cladurum*, Körn.
      ii. Awns long.
         a. Ears simple.
            * Narrow . . . . . . var. *rufum*, Körn.
            ** Broad and dense . . . . var. *pycnurum*, Körn.

I 2

FIG. 128 —EMMER (*T. dicoccum*, Schübl.).

var. *Ajar*.
Indian Emmer (1, non-irrigated ; 2, irrigated plant).

b. Ears with double spikelets . . . . var. *Schübleri*, Körn.
c. Ears branched . . . . . . var. *erythrurum*, Körn.

(4) Glumes red, pubescent.
i. Awns short.
a. Ears simple . . . . . . var. *Bauhini*, Körn.
b. Ears with double spikelets . . . var. *Tragi*, Körn.
c. Ears branched . . . . . . var. *Krausei*, Körn.
ii. Awns long.
a. Ears simple . . . . . var. *macratherum*, Körn.
b. Ears with double spikelets . . . var. *Mazzucati*, Körn.
c. Ears branched . . . . . var. *rubriramosum*, Körn.

(5) Glumes black, pubescent.
i. Awns short . . . . var. *subatratum*, Körn.
ii. Awns long.
a. Ears simple . . . . . . var. *atratum*, Körn.
b. Ears branched . . . . . . var. *melanurum*, Körn.

2. *Ears beardless or with short awns*—

(1) Glumes white, glabrous.
a. Ears simple . . . . var. *inerme*, Körn.
b. Ears with double spikelets . . var. *bispiculatum*, Körn.
c. Ears branched . . . . . var. *leucocladon*, Körn.

(2) Glumes white, pubescent.
a. Ears simple . . . . var. *muticum*, Körn.

(3) Glumes red, glabrous.
a. Ears simple . . . . var. *novicium*, Körn.
b. Ears branched . . . . . var. *subcladurum*, Körn.

(4) Glumes red, pubescent.
a. Ears simple . . . . var. *hybridum*, Körn.

Group I.—Indo-Abyssinian Emmers

Section A.—*Speltae*. Rachis fragile.

Ear bearded ; glumes white, glabrous ; grain red.

T. dicoccum, var. **Ajar**, mihi.
T. Arras, Hochst. *Flora*, 31, 450 (1848).

1. **Abyssinian Emmer** (2, Fig. 129).—This variety I obtained under the native Amharic name " Ajar " or " Agga," from Abyssinia, where it is grown at an elevation of 5000-8000 feet. It is sown in June and harvested in October, giving a six- to eight-fold return ; where irrigated it is sown in November and December and reaped in May.

It is closely related to the wild *T. dicoccoides* and, like it, is exceptionally early, coming into ear at Reading about May 20-25 when sown in autumn (October-December).

Coleoptiles, 4- to 6-nerved, sometimes pinkish.

Young shoots, erect; young leaves pubescent; the blades of the culm leaves less pubescent and a yellow-green tint; lower leaf-sheaths pink; auricles glabrous or with a few long hairs only.

Straw, very short, rarely more than 60 cm. (23-24 inches) long.

Ears, short, 6-7 cm. long, on non-irrigated land; flat, never glaucous, but a characteristic yellow-green colour becoming white or pinkish, like some glabrous forms of *T. hermonis*.

Rachis very fragile, thin, fringed along its edges with short hairs; frontal tufts short. Spikelets 16-20; 10-12 mm. long, 5-7 mm. broad, containing one or two pale reddish flinty grains; D = about 30; awns 9-12 cm. long.

Empty glume, 10 mm. long, narrow, 2·5-3 mm. across, keeled, apex more or less truncate with a short blunt apical tooth; secondary tooth and nerve distinct.

Grain, pale reddish, flinty, 9-10 mm. long, 3 mm. broad.

2. **Indian Emmer; Khapli** (Fig. 128).—This variety, sometimes erroneously described as *T. Spelta*, is grown in the Central Provinces, Madras, Bombay, and Mysore. It agrees in all its characters with Abyssinian Emmer, and the two forms I have no doubt have had a common origin.

SECTION B.—*Tenaces*. Rachis more or less tough.

Ear bearded; glumes white, glabrous; awns white; grain red.

T. dicoccum, var. **uncinatum**, mihi.

An early variety received from Abyssinia under the name **Nach Sinde.** Two forms appeared, viz.:

1. FORM 1 (2, Fig. 131).

Young shoots, erect; young leaves pubescent.

Straw, slender, short, solid or hollow with thick walls.

Ear, 5-9 cm. long, square, 10 mm. across the sides; spikelets 14-20, sometimes 3-grained; D = about 25; awns slender, 3-5 cm. long.

Empty glume, 8-9 mm. long, keeled, apical tooth strong, curved inwards (1, Fig. 125).

Grain, flinty or semi-flinty, compressed laterally with prominent dorsal hump; apex bluntish; "brush" short, 6·5-7·4 mm. long, 2·6-3·3 mm. broad, 2·9-4 mm. thick.

2. FORM 2.—An early variety received from Abyssinia in a sample of the violet-grained var. *Arraseita* (see below), from which it differs only in the colour of its grain.

Young shoots, erect; young leaves pubescent.

Straw, short, slender, 56-66 cm. (about 22 inches) long, upper internode hollow with thick walls.

Ear, slender, 8-9 cm. long, square, 10-11 mm. across the sides; spikelets 23; D = 31; awns 10-13 cm. long (Ear type, Fig. 130).

Empty glume, 9-10 mm. long, apical tooth narrow, straight or slightly curved, acute (2 and 3, Fig. 125).

Grain, flinty, with pointed apex 8-8·6 mm. long, 3·4 mm. broad, 3·6 mm. thick.

1 2

FIG. 129.—EMMER (*T. dicoccum*, Schübl.).

1. var. *farrum*. (White Russian Emmer.)

2. var. *Ajar*. (Abyssinian Emmer.)

Ear bearded ; glumes white with dark margins, glabrous ; awns black ; grain red.

T. dicoccum, var. **pseudo-uncinatum**, mihi.

This variety is similar to Form 2, var. *uncinatum*, but usually has a black stripe along the outer margin of the empty glume ; in some seasons the whole glume is a dark brown tint. It was obtained from the same source as Form 2, var. *uncinatum*.

Ear bearded ; glumes white, glabrous ; awns white ; grain violet.

T. dicoccum, var. **Arraseita**, mihi.

T. durum, var. *Arraseita*, Hochst *ex* Körn. *Handb. d. Getr.* i. 70 (1885).

T. durum, var. *Hildebrandti*, Wittmack. *Ber. Naturf.-Vers. Baden-Baden*, 211 (1879) ?.

T. " *Eloboni*," Caporn. *Journal of Genetics*, vii. 259 (1918).

Hochstetter's plants were grown from a sample of violet-coloured grains sent from Abyssinia by W. Schimper under the name " Arraseita." From the same sample var. *Schimperi* (p. 196) was also obtained.

Tukur Sinde (Fig. 130).—This variety is a very distinct, early short-strawed form with violet-coloured grain, received from Abyssinia under the name " Tukur Sinde."

Young shoots, erect ; young leaves more or less pubescent.

Straw, short to medium height, 76-90 cm. (about 30-36 inches) long, upper internode solid.

Ear, slender, narrow, 8·5-9 cm. long, compressed, 5-6 mm. across the face, 8-9 mm. across the side ; spikelets 21, 2-grained ; density variable = 20-30 ; awns 10 cm. long.

Empty glume, narrow, 9 mm. long ; sometimes with a dark marginal stripe, apical tooth narrow, acute (2, 4, Fig. 125).

Grain, narrow, a rich purple tint when fresh ; 8·5-8·9 mm. long, 3·5 mm. broad, 3·2 mm. thick.

Ear bearded ; glumes white, pubescent ; grain white.

T. dicoccum, var. **tomentosum**, mihi.

A characteristic variety with somewhat dense narrow ears, received from Abyssinia in a sample named **Nach Sinde** (1, Fig. 131).

Young shoots, erect ; young leaves pubescent.

Straw, slender, stiff, hollow with thick walls.

Ear, small, dense, 5-6 cm. long, oblong in section, 8-9 mm. across the face, 11 mm. across the two-rowed side ; spikelets 19-20 ; D = 35-36 ; awns 6-8 cm. long.

Empty glume, narrow, 9-10 mm. long, 2-2·5 mm. broad, apical tooth blunt, short, curved outwards, secondary notch and vein prominent (6, Fig. 125).

Grain, white or amber, flinty, compressed laterally, apex blunt, brush very short ; 7·7 mm. long, 2·4-2·7 mm. broad, 2·9-3·1 mm. thick.

Ear bearded ; glume red, glabrous ; grain red.

T. dicoccum, var. **rufescens**, mihi.

Received from Abyssinia in a sample of **Nach Sinde**.

Young shoots, erect ; young leaves pubescent.

Straw, very slender, short, hollow with thick walls.

Ear, narrow, lax, 7-8 cm. long, square, 8-10 mm. across the sides ; spikelets 14-18 ; D = about 25. Awns slender, spreading somewhat, 9-10 cm. long (Ear type 2, Fig. 130).

Empty glume, 9-10 mm. long, keeled throughout ; apical tooth short, blunt ; secondary notch distinct (5, Fig. 125).

Grain, flinty, with blunt apex, " brush " short, dorsal hump prominent ; 7·75 mm. long, 3·45 mm. broad, 3·3-3·4 mm. thick.

Ear bearded ; glumes red, glabrous ; grain purple.

T. dicoccum, var. **Schimperi**, mihi.

T. durum, var. *Schimperi*, Körn. *Handb. d. Getr.* i. 71 (1885).

Körnicke states that this purple-grained variety was sent from Abyssinia by Schimper in a mixed sample of var. *Arraseita*, which it resembles in all its characters except the colour of its glumes.

Ear bearded ; glumes dark brown or mottled, pubescent.

T. dicoccum, var. **persicum**, mihi.

Persian Black Wheat (Ear type 1, Fig. 130).—A remarkable wheat obtained from Haage and Schmidt, Erfurt, Germany ; very late, not coming into ear at Reading until the second or third week in June. It has been described as a variety of *T. vulgare*, var. *fuliginosum*, but its 3- to 4-nerved coleoptile, pubescent, grass-green leaves, slender thick-walled or solid straw, narrow rachis, and general form of ear place it near the Abyssinian Tukur Sinde (p. 195).

Vavilov found it perfectly immune to *Erysiphe graminis*, and in this respect quite unlike 580 sorts of *T. vulgare* which he tested at the same time.

The hybrid (F_1) with *T. vulgare* is almost sterile.

Young shoots, erect ; young leaves pubescent.

Straw, thin, of medium height, 104 cm. (about 42 inches), solid or hollow with thick walls ; nodes hairy.

Ear, very lax, narrow, 9 cm. long, square, 10 cm. across the sides ; spikelets 2- to 3-grained, 19-20 ; D = about 20.

Empty glume, with a long awn 3-4 cm. long (7, Fig. 125).

Flowering glume, white below, dark brown above, with awn 8-11 cm. long.

Grain, flinty, reddish ; apex blunt ; 6·5 mm. long, 3 mm. broad, 2·9 mm. thick.

Group II.—European Emmers.

Ear bearded ; awns short ; glumes white, glabrous.

T. dicoccum, var. **tricoccum**, Körn. *Handb. d. Getr.* i. 86 (1885).

T. tricoccum, Schübl. *Char. et descr. Cer.* 33 (1818), and *Flora*, 445 (1820).

FIG. 130.—EMMER (*T. dicoccum*, Schübl.).

var. *Arraseita*.
Tukur Sinde: Abyssinian Purple-grained Emmer.
(1, lax; 2, dense-eared form.)

T. amyleum, G., Metzger. *Eur. Cer.* 33, Taf. 7 B. (1824); *Landw. Pfl.* i. 114 (*c*) (1841).

T. amyleum, Ser., Krause. *Getr.* Heft V. 13, t. 5 D. (1837).

T. vulgare subtricoccum, Alef. *Landw. Fl.* 332 (1866).

Egyptian Spelt; Egyptian Winter Wheat.—A somewhat hardy form, described by Schübler, Metzger, and others. I have not seen it, but think it probable that it is similar to Form 1, var. *uncinatum*, mihi, and should be placed in Group I.

Straw, 120-150 cm. high; leaves yellowish-green.

Ear, 10-12 cm. long, with short awns. D=28. The spikelets are about 1 cm. broad and contain two or three reddish flinty or mealy grains 9 mm. long and 4 mm. broad.

Now rare, but formerly grown in Egypt, Italy, south of France, and the Jura in Switzerland.

Ear bearded, narrow; awns long; glumes white, glabrous.

T. dicoccum, var. **farrum**, Körn. *Handb. d. Getr.* i. 87 (1885).

T. farrum, Bayle-Barelle. *Mon. d. Cer.* 50 (1809).

T. dicoccum album, Schübler. *Char. et descr. Cer.* 29 (1818), and in *Flora Jahr.* 3, ii. 450.

The commonest European variety of *T. amyleum*. Three forms of it are distinguished.

1. **White Emmer** (*T. amyleum*, A., Metzger, *Eur. Cer.* 30) (1, Fig. 132).—A late form found in small quantities in France, Germany, Austria, Switzerland, Italy, and Spain. It comes into ear at Reading from June 10 to 20.

Young shoots, erect; young leaves pubescent.

Straw, 100 cm. (40 inches) long.

Ear, dense, 7-9 cm. long, narrow, 9 mm. across the 2-rowed side; spikelets 27-28; D=38; awns 6-8 cm. long.

Empty glume, 8-9 mm. long, 3 mm. broad, keeled to the base, apex with long, curved, claw-like tooth (9, Fig. 125); secondary lateral nerve prominent, ending in a short tooth, near the base of the keel tooth.

Grain, flinty, brownish-red; 7-8 mm. long, 3 mm. broad.

2. **Large White Emmer** (*T. amyleum*, B., Metzger, *Eur. Cer.* 31) (2, Fig. 132).—A taller form found with the preceding variety; it is about a week later in ripening.

Straw, 130 cm. (50 inches) long.

Ear, larger and laxer, 10-12 cm. long, 1-1·2 cm. broad, keeled, spikelets about 30; D=31. The edges of the rachis are fringed with long hairs; spikelets 12-13 mm. long, 7 mm. broad; awns 7-9 cm. long.

Empty glume, 9-10 mm. long, 4 mm. broad; apex narrow; apical tooth short, straight, acute; secondary nerve ending in a blunt tooth (8, Fig. 125).

Grain, semi-flinty, reddish-yellow, 8-9 mm. long, 3·5 mm. broad, with prominent dorsal ridge.

3. **Slav Emmer** (1, Fig. 129).—A small-eared form cultivated in Serbia and Russia, chiefly in the provinces adjacent to the Volga and to a lesser extent in the Caucasus, Siberia, and Turkestan. It is somewhat earlier than the preceding form, coming into ear at Reading about ten days sooner.

Young shoots, erect; young leaves pubescent.

Straw, 90-95 cm. (36-38 inches) long.

Ear, small and short, 5-7 cm. long, 1 cm. across the 2-rowed side; spikelets 23-25; D=38-40; awns 6-8 cm. long.

Empty glume, 8 mm. long, 3 mm. broad, apex with short blunt tooth (12, Fig. 125).

Grain, red and flinty, pointed at both ends, "brush" long, dorsal ridge prominent; 7·5 mm. long, 2·5-2·7 mm. broad, 2·4-2·6 mm. thick.

Ear bearded, broad, dense; glumes white, glabrous.

T. dicoccum, var. **liguliforme**, Körn. *Handb. d. Getr.* i. 90 (1885).

T. amyleum, Ser., Krause. *Getr.* Heft V. 9, t. 4 C. D. (1837).

A variety with short dense ears 5 cm. long and 1·8 cm. broad, frequently bent over on the flat side; the awns 12-15 cm. long. Körnicke states that he received this variety from Jena.

Ear bearded, branched; glumes white, glabrous.

T. dicoccum, var. **albiramosum**, Körn. *Arch. f. Biontologie*, ii. 411 (1908).

Apparently a hybrid discovered by Körnicke in the Botanic Garden at Poppelsdorf in 1901.

Ear, with short awns; glumes white, pubescent.

T. dicoccum, var. **submajus**, Körn. *Arch. f. Biontologie*, ii. 409 (1908).

Ears like var. *majus*, but with short black or white awns.

Found by Körnicke in a mixture in the Botanic Garden, Poppelsdorf.

Ear bearded, branched; awns short; glumes white, pubescent.

T. dicoccum, var. **Metzgeri**, Körn. *Handb. d. Getr.* i. 91 (1885).

T. amyleum, Ser., Krause. *Getr.* Heft V. 15, Taf. 6 C. (1837).

T. amyleum, D., Metzger. *Eur. Cer.* 32 (1824), and *Landw. Pfl.* i. 116 (*e*) (1841).

T. vulgare Metzgeri, Alef. *Landw. Fl.* 332 (1866).

This variety is not constant; its simple ears resemble those of the preceding variety.

Ear bearded, lax; awns long, straight; glumes greyish-white, pubescent.

T. dicoccum, var. **semicanum**, Körn. *Handb. d. Getr.* i. 89 (1885).

T. amyleum, C., Seringe. *Mél. bot.* 128 (1818).

T. amyleum, C., Metzger. *Eur. Cer.* 32 (1824).

1 2

FIG. 131.—EMMER (*T. dicoccum*, Schübl.).

1. var. *tomentosum*. (Abyssinia.)

2. var. *uncinatum*. (Abyssinia.)

T. amyleum, Ser., Krause. *Getr.* Heft V. 47 (1837).

The ears of this variety are short, narrow, and lax, 5-6 cm. long, 1·2 cm. broad, and the awns blackish. The grains are pale red, flinty, and loosely invested by the glumes. Received by Körnicke from Jena, and believed by him to be descended from Krause's stock.

Ear bearded, narrow, lax ; awns long, usually black and bent ; glumes white, pubescent.

T. dicoccum, var. **flexuosum**, Körn. *Handb. d. Getr.* i. 88 (1885).

A white velvet-chaffed form, with very lax fragile ears and awns 8-10 cm. long, generally black and bent at the base. The grain is large, red, and flinty, 7·5 mm. long, 3-5 mm. broad, and loosely invested by the glumes.

Körnicke received it from Jena mixed with the straight-awned var. *semicanum*.

Ear bearded, broad, dense ; awns long, black ; glumes white, pubescent.

T. dicoccum, var. **majus**, Körn. *Handb. d. Getr.* i. 89 (1885).

T. amyleum, Ser., Krause. *Getr.* Heft V. 8, t. 3 A. (1837).

Received by Krause from a Botanic Garden under the title " *T. vulgare* or *turgidum cochleare*."

A very tall, strong-growing variety 140-150 cm. high, with broad ears 10-12 mm. long, tapering upwards, and consisting of 22-24 spikelets containing pale reddish-yellow mealy or semi-flinty grains 8 mm. long, 3·5 mm. broad, loosely held in the glumes. The awns are dark brown or black and 15-17 mm. long.

Received by Körnicke from Hohenheim.

Ear with short awns ; glumes red, glabrous.

T. dicoccum, var. **Fuchsii**, Körn. *Handb. d. Getr.* i. 87 (1885).

T. vulgare Fuchsii, Alef. *Landw. Fl.* 332 (1866).

A variety obtained in 1824 by Metzger from the white-chaffed var. *Metzgeri*.

Ear with double spikelets and short awns ; glumes red, glabrous.

T. dicoccum, var. **Dodonaei**, Körn. *Arch. f. Biontologie*, ii. 410 (1908).

Ear branched ; awns short ; glumes red, glabrous.

T. dicoccum, var. **cladurum**, Körn. *Handb. d. Getr.* i. 90 (1885).

T. amyleum, Ser., Krause. *Getr.* Heft V. ii. t. 5 C. (1837).

T. vulgare cladura, Alef. *Landw. Fl.* 333 (1866).

Alefeld obtained this variety from var. *Fuchsii*.

Körnicke received it from a Botanic Garden and states that only a certain proportion of the ears are branched, and in these the branching is not pronounced.

The commonest form of it has very tall straws, 130-140 cm. long, branched ears with a toughish rachis and awns 4-5 cm. long. The grains are reddish-yellow and mealy, small, 6 mm. long, 3-3·5 mm. broad.

Ear bearded, narrow ; awns long ; glumes red, glabrous.

T. dicoccum, var. **rufum**, Körn. *Handb. d. Getr.* i. 88 (1885).

T. dicoccum rufum, Schübl. *Char. et descr. Cer.* 29 (1818).

T. amyleum, Ser., Krause. *Getr.* Heft V. 5, Taf. 2 A. B. (1837).

T. amyleum, E., Metzger. *Eur. Cer.* 32 (1824), and *Landw. Pfl.* i. 114 (*b*) (1841).

T. vulgare brunneum, Alef. *Landw. Fl.* 331 (1866).

This variety has red glumes, but in other respects resembles the white-glumed var. *farrum*, with which it is generally found mixed.

I have met with two forms, viz.: (1) a small-eared, short-strawed Serbian and Russian form with blunt-ended empty glumes (1, Fig. 133), and (2) the Western European Red Emmer (2, Fig. 133), with taller straw, larger ears, later habit, and empty glumes, with a claw-like apical tooth similar to that of White Emmer (p. 197).

Ear bearded, broad, and dense ; awns long ; glumes red, glabrous.

T. dicoccum, var. **pycnurum**, Körn. *Handb. d. Getr.* i. 90 (1885).

T. vulgare pycnura, Alef. *Landw. Fl.* 333 (1866).

Two forms are recognised, viz.:

Form 1. (*T. amyleum*, I., Metzger, *Eur. Cer.* 34) with pale red short ears 4-5 cm. long, 1·6 cm. broad, tapering towards both ends; awns 16-18 cm. long; spikelets occasionally with three grains, which are less firmly enclosed in the glumes than in most Emmers.

Sent to Körnicke from Hohenheim as *T. Cienfuegos* and from some Botanic Gardens as *T. Hisbu*.

Form 2 has dark red, longer ears 5-7 cm. long, 1·4 cm. broad, and widest at the apex; awns 12-16 cm. long (figured by Krause, *Getr.* Heft. V. 9, t. 4 A. B.).

Ear bearded with doube spikelets ; awns long ; glumes red, glabrous.

T. dicoccum, var. **Schübleri**, Körn. *Arch. f. Biontologie*, ii. 410 (1908).

Found by Körnicke in 1899 in the Botanic Garden at Poppelsdorf among var. *erythrurum*; he states that the grains are loosely held by the chaff, and presumes it is a hybrid with some form of *T. vulgare*.

Ear branched ; awns long ; glumes red, glabrous.

T. dicoccum, var. **erythrurum**, Körn. *Handb. d. Getr.* i. 91 (1885).

T. amyleum, F., Metzger. *Eur. Cer.* 33 (1824).

T. vulgare phaeocladus, Alef. *Landw. Fl.* 332 (1866).

Körnicke's examples were derived from a cross.

Ear with short awns ; glumes red, pubescent.

T. dicoccum, var. **Bauhini**, Körn. *Handb. d. Getr.* i. 87 (1885).

T. amyleum, H., Metzger. *Eur. Cer.* 33 (1824).

T. vulgare Bauhini, Alef. *Landw. Fl.* 332 (1866).

1 2

FIG. 132.—EMMER (*T. dicoccum*, Schübl.).

var. *farrum*.

1. White Emmer. 2. Large White Emmer.

(European forms.)

The straw of this variety is very tall, 140-150 cm. (55-60 inches) high, ears 10-12 cm. long, with a toughish rachis and small reddish-yellow mealy grains 7 mm. long and 3·5 mm. broad, loosely invested by the glumes.

Obtained from a Botanic Garden by Körnicke.

Ear with short awns and double spikelets ; glumes red, pubescent.

T. dicoccum, var. **Tragi**, Körn. *Handb. d. Getr.* i. 90 (1885).
Körnicke's type was obtained from a Botanic Garden.

Ear branched ; awns short ; glumes red, pubescent.

T. dicoccum, var. **Krausei**, Körn. *Handb. d. Getr.* i. 91 (1885).
A common form of this variety has very tall straw, 140-150 cm. (55-60 inches) high ; the ears are dense and branched at the base, with small reddish-yellow mealy and flinty grains 7 mm. long, 2·5 mm. broad, which are loosely enclosed by the glumes. The short slender awns are pale red and are only found on the flowering glumes of the lower of the two flowers of each spikelet.

Obtained from a cross.

Ear bearded ; awns long ; glumes red, pubescent.

T. dicoccum, var. **macratherum**, Körn. *Handb. d. Getr.* i. 89 (1885).
Körnicke's type was obtained from a Botanic Garden.

Ear with double spikelets, bearded ; awns long ; glumes red, pubescent.

T. dicoccum, var. **Mazzucati**, Körn. *Arch. f. Biontologie*, ii. 410 (1908).
Originated in 1895 from a form with branched ears. Körnicke suggests that it arose from the crossing of a branched Emmer with *T. vulgare*.

Ear branched, bearded ; awns long ; glumes red, pubescent.

T. dicoccum, var. **rubriramosum**, Körn. *Arch. f. Biontologie*, ii. 411 (1908).
Appeared in the Botanic Garden, Poppelsdorf, among a sowing of var. *albiramosum* in 1904.

Ear bearded ; awns short ; glumes blue-black, pubescent.

T. dicoccum, var. **subatratum**, Körn. *Arch. f. Biontologie*, ii. 409 (1908).
Discovered by Körnicke in 1884 in the Botanic Garden, Poppelsdorf.

Ear bearded ; awns long ; glumes blue-black, pubescent.

T. dicoccum, var. **atratum**, Körn. *Handb. d. Getr.* i. 89 (1885).
T. atratum, Host. *Gram. austr.* iv. 5 and 8 (1809).
T. atratum, Roem. et Schult. *Syst. vegetab.* ii. 766, No. 15 (1817).
T. atratum, Schübl. *Char. et descr. Cer.* 32 (1818).
T. amyleum, D., Ser. *Mél. bot.* 129 (1818).

T. amyleum, K., Metzger. *Eur. Cer.* 32 (1824); *Landw. Pfl.* i. 117 h. (1841).
T. amyleum, Ser., Krause. *Getr.* Heft V. 3 Pl. I. A. B. (1837).

Black Emmer (3, Fig. 133).—A common representative of this variety is Black Winter Emmer, a very late form, the ears of which do not escape from the upper sheath until about June 20 at Reading.

Körnicke states it is of African origin, and Heuzé says it is believed to have come from Abyssinia.

Although much more hardy it yields less grain than the white-chaffed forms of var. *farrum*.

Small plots of Black Winter Emmer appear to be grown in France and Germany.

It was introduced from France in 1904 into the United States, where it is sometimes grown as food for stock in place of oats and barley.

Young shoots, prostrate in winter and early spring.

Straw, of medium height to tall, about 102-115 cm. (40-46 inches) long.

Ear, very dense and flat, broad at the base, tapering towards the apex; 7-8 cm. long, about 1·6 cm. broad, with 26-28 spikelets; D = 46. The spikelets are 10-12 mm. long, 5 mm. broad, each with two small reddish-yellow, opaque, mealy grains 6-7 mm. long, 2·5 mm. broad.

Empty glume, 9-10 mm. long, 3 mm. broad, bluish-black or brownish with a glaucous hue and clothed with fine hairs, the colour of the hidden portions of the flowering glumes being a pale reddish-white. The keel terminates in a short bluntish tooth (11, Fig. 125).

The awns of the flowering glume are slender and brownish, those of the lower flower of the spikelet being 8-9 cm. long, those of the upper flower 3-4 cm. long.

Grain, red, mealy, pointed at both ends, with prominent dorsal ridge; 8·3 mm. long, 3 mm. broad, 3 mm. thick.

Ear branched, bearded; awns long; glumes blue-black, pubescent.

T. dicoccum, var. melanurum, Körn. *Handb. d. Getr.* i. 91 (1885).
T. amyleum, L., Metzger. *Eur. Cer.* 35 (1825); *Landw. Pfl.* i. 118 bb. (1841).
T. vulgare melanura, Alef. *Landw. Fl.* 333 (1866).

The ear is slightly branched or bears only double spikelets at the notches on the lower half of the rachis. Some of the ears are simple but produce branched examples when their grain is sown. Metzger states that the variety is the branched form of the Black Winter Emmer (var. *atratum*), but Körnicke found that the simple ears differed somewhat from the latter.

Ear beardless; glumes white, glabrous.

T. dicoccum, var. inerme, Körn. *Arch. f. Biontologie*, Bd. ii. 408 (1908).

Discovered by Körnicke in the Botanic Garden at Poppelsdorf, and derived from var. *semicanum*. It differs from typical *T. dicoccum* in having ears broader across the face than across the 2-rowed side.

1 2 3

Fig. 133.—Emmer (*T. dicoccum*, Schübl.).

var. *rufum*.
1. Russian Red Emmer.
2. European Red Emmer.

var. *atratum*.
3. Black Emmer.

Ear with double spikelets, beardless ; glume white, glabrous.

T. dicoccum, var. **bispiculatum**, Körn. *Arch. f. Biontologie*, ii. 410 (1908).

Derived from var. *semicanum* ; apparently of hybrid origin and discovered by Körnicke in 1883 in the Botanic Garden, Poppelsdorf.

Ear branched, beardless ; glume white, glabrous.

T. dicoccum, var. **leucocladum**, Körn. *Handb. d. Getr.* i. 90 (1885).

T. vulgare leucocladus, Alef. *Landw. Flora*, 332 (1866).

Alefeld states that this variety originated from var. *tricoccum* and is not constant.

Ear beardless ; glumes white, pubescent.

T. dicoccum, var. **muticum**, Körn. *Handb. d. Getr.* i. 86 (1885).

Formerly cultivated extensively in the Trentino (Körnicke).

Ear beardless ; glumes red, glabrous.

T. dicoccum, var. **novicium**, Körn. *Arch. f. Biontologie*, ii. 408 (1908).

Apparently a hybrid derived from var. *cladurum*. Discovered in the Botanic Garden at Poppelsdorf.

Ear branched, beardless ; glumes red, glabrous.

T. dicoccum, var. **subcladurum**, Körn. *Arch. f. Biontologie*, ii. 410 (1908).

Apparently of hybrid origin and discovered by Körnicke in the Botanic Garden at Poppelsdorf in 1892.

Ear beardless ; glumes red, pubescent.

T. dicoccum, var. **hybridum**, Körn. *Arch. f. Biontologie*, ii. 409 (1908).

A hybrid discovered by Körnicke in 1881 in the Botanic Garden at Poppelsdorf.

CHAPTER XIV

KHORASAN WHEAT

Triticum orientale, mihi.

A SMALL but distinct race of wheat sent by Sir Percy Sykes from Khorasan, Persia, where it is cultivated on irrigated land. At Reading it is among the earliest wheats, coming into ear about the end of May.

In its narrow pubescent leaves, very lax ears, scabrid awns, very long grain, and early habit it is clearly related to *T. dicoccoides* and *T. dicoccum* and unlike *T. durum*.

In form of ear and length of grain it closely resembles some of the varieties of *T. polonicum* figured by Seringe.

The plants at Reading are often cleistogamous and their fertility much reduced, especially in damp seasons, when the anthers remain minute and the filaments of the stamens do not lengthen.

General Characters of *T. orientale*, mihi.

The coleoptile is 2-nerved.

The young shoots are erect, with very narrow pubescent leaves. The plants tiller very little and the straw is thin, reed-like, short or of medium height, 66-110 cm. (26-44 inches) long, the upper internode solid or hollow with thick walls.

The ears are long, narrow, very lax, with a tough rachis and 10-11·5 cm. long, almost square, 10-11 mm. across the sides or 10-11 mm. across the face and 8-9 mm. across the 2-rowed side ; density, 16-18.

The spikelets (16-20) are 2- to 3-grained, with more or less deciduous awns, 12-13 cm. long, scabrid to the base. The sides of the rachis are fringed with white hairs, and there is a conspicuous frontal tuft below each spikelet ; the internodes are narrow and wedge-shaped, each about 1·5 mm. wide at the base and 3 mm. at the top.

The empty glumes are white, pubescent, 12-15 mm. long and 4 mm. broad, keeled to the base, with a short apical tooth ; lateral nerve prominent (Fig. 134).

The flowering glume bears a coarse awn, scabrid to the base, 14-16 cm. long.

1 2

FIG. 136.—KHORASAN WHEAT (*T. orientale*, mihi).

1. var. *notabile*.
(Siah Das.)

2. var. *insigne*.
(Shutar Dandan.)

The grains are very long, narrow, white, and flinty, resembling those of *T. polonicum* and the largest-grained forms of *T. dicoccoides*, being 10·5-12 mm. long, 3 mm. broad, 3·2-3·4 mm. thick (Figs. 134, 135).

VARIETIES OF *T. orientale*, mihi.

Two varieties are found differing only in the colour of the awns.

1. Ear bearded ; glumes white, pubescent ; awns white . var. *insigne*.
2. Ear bearded ; glumes white, pubescent ; awns black . var. *notabile*.

Ear bearded ; glumes white, pubescent ; awns white ; grain white.

T. orientale, var. insigne, mihi.

FIG. 134.—Empty glume (× 2) and grain (front, back, and side views, nat. size) of Khorasan wheat (*T. orientale*).

Shutar Dandan (=Camel's tooth) (1, Fig. 136).—A distinct very early variety, with long lax ears, and long narrow glumes and grains. It comes into ear at Reading during the last week of May.

Young shoots, erect ; young leaves very narrow, pubescent.

Straw, thin, reedy, of medium height, 95-110 cm. (38-44 inches long) ; upper internode solid or hollow with thick walls.

Ear, long, very lax, narrow ; 10-11·5 cm. long, almost square, 10-11 mm. across the sides or 10-11 mm. across the face and 8-9 mm. across the side ; spikelets 16-20, 2- to 3-grained ; awns 13-17 cm. long, deciduous, scabrid to the base ; D = 16-18.

Empty glume, white, pubescent, long and narrow ; keeled to the base, 12-15 mm. long, 4 mm. wide ; apical tooth short (Fig. 134).

Grain, very long, white, flinty, 10·5-12 mm. long, 2·75-3·0 mm. broad, 3·2-3·4 mm. thick.

FIG. 135.—Grains of the spikelets of one side of an ear of Khorasan wheat (*T. orientale*) (nat. size).

Ear bearded ; glumes white, pubescent ; awns black ; grain white.

T. orientale, var. notabile, mihi.

Siah Das (=Black Hand) (2, Fig. 136).—This variety was sent by Sir Percy Sykes from Khorasan with the preceding variety, from which it differs only in the possession of jet black awns.

CHAPTER XV

MACARONI WHEAT

Triticum durum, Desf. *Fl. Atlant.* i. 114 (1798).
T. sativum, γ, *durum*, Pers. *Syn. Pl.* i. 109 (1805).
T. vulgare durum, Alef. *Landw. Fl.* 324 (1866).
T. sativum durum, Hackel. *Nat. Pfl.* ii. 2, 85 (1887).
T. tenax, B. II., *durum*, Asch. und Graeb. *Syn.* ii. 692 (1901).
T. alatum, Peterm. in *Flora*, xxvii. 234 (1844) is often given as a synonym of *T. durum*, although Petermann specifically states that it is different from *T. durum*; it has some characters of *T. turgidum*, and its place cannot be determined at present.

MACARONI Wheat is frequently named Hard Wheat on account of the hard flinty nature of its grain; as the term "hard" is, however, often applied in the cereal markets to samples of North American Bread Wheats (*T. vulgare*), it is advisable to use the name Macaroni Wheat for this race.

No authenticated specimens of ears or grain of *T. durum* of prehistoric age are known, and there are no trustworthy data regarding its cultivation in early historic times.

Grains discovered by Schliemann in a "pithos" when excavating the walls of Hissarlik have been referred to *T. durum* by Wittmack and Körnicke. Seringe states that grains of this race have been obtained from the wrappings of Egyptian mummies; these were probably modern and accidentally or fraudulently introduced.

In excavations of the cemetery at Hawara in Egypt Professor Flinders Petrie found a number of well-preserved ears and grains of wheat in a grave of the Graeco-Roman period dating from about the first century B.C. Examples of these in the British Museum (Nat. Hist. Dept.) closely resemble forms of *T. durum*, some of them with glabrous, others with pubescent glumes, strongly keeled to the base; the grains are small and plump, with pointed base, narrowed apex, and high dorsal ridge, the average dimensions being 7·1 mm. long, 3·1 mm. broad, and 3·25 mm. thick.

Ears with keeled pubescent glumes and grains resembling those of

T. durum were found at Kahun in Egypt in tombs of the XIIth Dynasty (2000 B.C.).

The earliest historical reference to this wheat is made by Dodoens in his *Historia frumentorum*, published in 1566. Some grains found by him among the grains of Canary grass (*Phalaris canariensis*) obtained from Spain and the Canary Isles were sown, and gave rise to a form of wheat which he described and figured under the name *Triticum Typhinum*, apparently connecting it with the τίφη (*tiphe*) of ancient Greek authors. The latter is now regarded as *Triticum monococcum*, but the account and figure given by Dodoens leave no doubt that his plant was a form of Macaroni Wheat.

Not until near the end of the eighteenth century was *T. durum* distinguished from the Mediterranean forms of *T. turgidum* and *T. vulgare* by Desfontaines, who described it from Barbery in his *Flora Atlantica* (vol. i. p. 114) in 1798, mentioning solid straw, pubescent glumes, and long flinty grain as its specific characters.

Next to *T. vulgare* the various forms of *T. durum* are the most widely cultivated wheats of the present day. They are grown throughout the Mediterranean region, in Portugal, Spain, Italy, Morocco, Algeria, Egypt, Abyssinia, Greece, Bulgaria, Turkey, and Asia Minor.

The greatest amount is produced on the "Tchernozem" or black soil of Russia, especially in the region of the Volga. It is a common cereal in Turkestan, the Transcaucasus, and the southern portion of East Siberia, and is found in lesser amount in Bokhara, Persia, and India, but it does not extend to China or Japan.

In the Western Hemisphere it is cultivated in the United States, Canada, Mexico, the countries of Central America, Chili, and Argentina.

Small quantities are grown also in South Africa and Australia.

T. durum does not tiller much, but grows rapidly and succeeds best as a spring crop, although at Reading it ripens later than many common forms of *T. vulgare*. I have not met with any very early forms.

In regions possessing mild winters it may be sown in autumn, and in such localities often provides useful green herbage, which may be fed off lightly with stock during winter without damaging the yield of grain at harvest.

Macaroni Wheat requires a dry hot climate for satisfactory growth, the plants being easily damaged by frost. It possesses great power of resisting drought, giving fair yields of grain in regions where the rainfall is not more than 10-18 inches per annum. In districts too dry to allow of the cultivation of *T. vulgare*, *T. durum* will yield 10-20 bushels per acre, and crops of it have been raised in several semi-arid parts of the world where no rain has fallen between seed-time and harvest. Its growth is most prosperous, however, where a considerable proportion of the annual

rainfall occurs during the early part of the growing season, a few good showers alternating with bright sunshine and a dry atmosphere resulting in the highest yield of grain of fine quality. In addition to a suitable climate, a deep rich soil containing an abundance of humus and an adequate supply of lime, potash, and phosphates is necessary to secure the best returns.

The Macaroni Wheats are highly resistant to rust and smut fungi.

In Australia, where wheat is frequently utilised as a hay crop, some forms of *T. durum* have proved of especial value for this purpose. The Macaroni Wheats, however, are grown chiefly for their grain, the best samples of which are yellowish, translucent, and very hard and difficult to grind. In modern mills the grains undergo a process of " conditioning " before being ground.

In Russia and some other parts of the world a large amount of *durum* is used for bread-making, either by itself or mixed with 10-20 per cent of flour of Red-grained Bread Wheat (*T. vulgare*). The bread made from Macaroni Wheat is yellowish in colour, but of excellent flavour, and keeps fresh longer than that from Bread Wheat.

The high gluten-content and the physical quality of the protein of these wheats make them specially suited to the manufacture of macaroni, spaghetti, and other edible pastes, and large quantities are employed for this purpose, especially in France, Italy, and Spain. For the preparation of these pastes the grain is milled only as far as the " semolina " stage, a finely grained flour not being required. The dough formed from the semolina is subsequently forced through tubes or openings of various forms and sizes and then dried.

General Characters of *T. durum*

The young leaf-blades and shoots have almost always the erect " spring " habit (Fig. 65); I have seen none with the low spreading " winter " habit, and a few only in which the young leaf-blades are semi-erect, making an angle of 45°-60° with the soil surface in the early stages of their growth.

The leaves, which may be yellowish-green or bluish-green, are all glabrous in most varieties. In a small number of forms, which are probably hybrids, short hairs are present, especially on the surfaces of the lower leaves, the character of the hairs in some cases suggesting an affinity with *T. vulgare*, in others a relationship with *T. dicoccum* or *T. turgidum* (Fig. 137).

The culms are striate, from 75 to 150 cm. or more (about 30-60 inches) high, the surface somewhat dull and slightly rough; in some cases they are hollow with thick walls, but in most varieties they are solid throughout

or in the upper internodes. When well developed they possess 5 or 6 internodes above ground.

Except in the case of one or two varieties, which appear to be hybrids, the ears are always bearded, and either square in section or compressed laterally and oblong in section, in which latter case the 2-ranked side is generally wider than the face of the ear. They are from 4 to 11 cm. (about $1\frac{1}{2}$ to $4\frac{1}{4}$ inches) in length without the awns, having an average of 21 spikelets per ear, the density varying from about 20 to 47 per 10 cm. length of rachis.

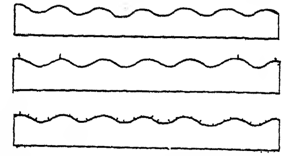


FIG. 137. — Diagrammatic transverse sections of young leaves of *T. durum* and *T. polonicum*.

The rachis is usually tough, though in some varieties it disarticulates more or less easily, especially near the base of the ear; it is fringed

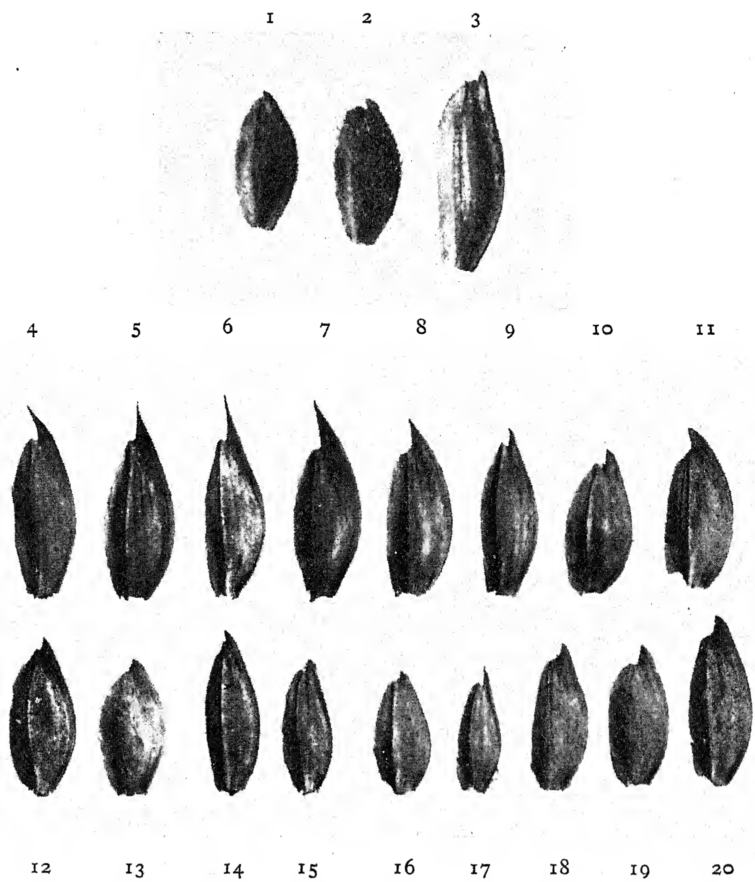
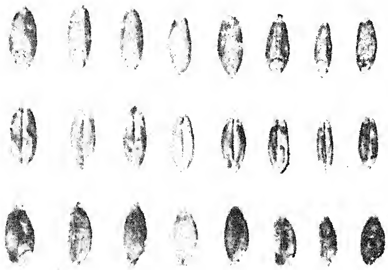


FIG. 138.—Empty glumes of Macaroni wheat (*T. durum*) (× 2).



1 2 3 4 5 6 7 8

FIG. 139.—Grains of Macaroni wheat (*T. durum*), front, back, and side views (nat. size).

along the margins with hairs, and bears a frontal tuft at the base of each spikelet.

The spikelets are 5- to 7-flowered, those of square ears ripening three or four grains, those of compressed ears usually only two; they are from 10 to 15 mm. long, 8-15 mm. broad, and 4-5 mm. thick.

The empty glumes are glabrous or hairy, the length and amount of the hair varying considerably. The colour is yellow, red, or blue-black in various shades. Those of the lateral spikelets are 8-12 mm. long, unsymmetrical, the outer face somewhat flat and measuring from the midrib to the outer edge 4-5 mm., the inner portion being 2-3 mm. wide. A prominent keel runs from the base to the tip. The apical tooth, which may be acute or blunt, is of variable length; the lateral secondary tooth in which the strong nerve on the outer face terminates being usually short or missing: the various forms of empty glumes are illustrated in Fig. 138.

The flowering glumes are thin and pale, rounded on the back with 9-15 nerves, the two lowest of each spikelet having long awns, measuring in some cases as much as 20-23 cm., those of the upper flowers of the spikelet usually having a length of ·5 to 4 cm. long.

The awns are white, red, or black, the latter tint, as in *T. turgidum* and other wheats (see p. 105), being developed to the greatest extent in dry bright weather, frequently failing to appear in dull humid seasons; they are

FIG. 140.—Grains of the spikelets on one side of an ear of Macaroni wheat (*T. durum*) (nat. size).

almost smooth near the base, thus differing from those of *T. turgidum*, which are usually scabrid throughout their whole length.

The awns are generally straight and more or less parallel to the sides of the ear, though in some varieties they are divergent and occasionally bent in a sinuous manner near the base; they are longer than those of any other wheats, varying from 11 to 23 cm. in length, and are more persistent than those of *T. turgidum*, except in some Indian forms, which lose their awns very readily when dead ripe.

The grains are usually white, amber, yellow, or red; the latter, when pale and flinty, are extremely difficult to distinguish from white or amber flinty grains.

The typical form is somewhat narrow, tapering towards both ends, more or less laterally compressed, with a narrow dorsal ridge, and wanting in plumpness, the shallow furrow usually having flattish sloping sides; the cross section is more or less triangular (Figs. 139, 140).

The endosperm is generally very hard and translucent with a vitreous or flinty fracture; a few varieties approximating towards *T. dicoccum* or *T. turgidum* have opaque mealy grains.

The embryo is large with an elongated oval scutellum. Measurements of grains taken from the middle of the ear of flinty forms gave the following results:

	Length.	Breadth.	Thickness.
	mm.	mm.	mm.
Average	8·30	3·48	3·61
Limits	7·0-9·7	2·8-4·1	3·2-4·25
Ratio	100	41·9	43·5

VARIETIES OF *T. durum*, Desf.

(1) *Ears bearded*—

1. Glumes white, glabrous; awns white.
   - *a.* Grain white . . . . . . var. *leucurum*, Körn.
   - *b.* Grain red . . . . var. *affine*, Körn.
2. Glumes white, glabrous; awns black.
   - *a.* Grain white . . . . . var. *leucomelan*, Körn.
   - *b.* Grain red . . . . . . var. *Reichenbachii*, Körn.
3. Glumes white, pubescent; awns white.
   - *a.* Grain white . . . . . . var. *Valenciae*, Körn.
   - *b.* Grain red . . . . . . var. *fastuosum*, Körn.
4. Glumes white, pubescent; awns black.
   - *a.* Grain white . . . . . var. *melanopus*, Körn.
   - *b.* Grain red . . . . . . var. *africanum*, Körn.

5. Glumes red, glabrous ; awns red.
   - *a.* Grain white . . . . . . var. *hordeiforme*, Körn.
   - *b.* Grain red . . . . var. *murciense*, Körn.

6. Glumes red, glabrous ; awns black.
   - *a.* Grain white . . . . . . var. *erythromelan*, Körn.
   - *b.* Grain red . . . . . . var. *alexandrinum*, Körn.

7. Glumes red, pubescent ; awns red.
   - *a.* Grain white . . . . var. *italicum*, Körn.
   - *b.* Grain red . . . . . . var. *aegyptiacum*, Körn.

8. Glumes red, pubescent ; awns black.
   - *a.* Grain white . . . . var. *apulicum*, Körn.
   - *b.* Grain red . . . . var. *niloticum*, Körn.

9. Glumes blue-black, glabrous.
   - *a.* Grain white . . . . . . var. *provinciale*, Körn.
   - *b.* Grain red . . . . var. *obscurum*, Körn.

10. Glumes blue-black, pubescent.
    - *a.* Grain white . . . . . . var. *coerulescens*, Körn.
    - *b.* Grain red . . . . var. *libycum*, Körn.

(2) *Ears beardless*—

1. Glumes blue-black, glabrous ; grain white. . var. *australe*, mihi.
2. Glumes red, glabrous ; grain white . . var. *sub-australe*, mihi.

Ear bearded ; glumes white, glabrous ; awns white ; grains white.

T. durum, var. **leucurum**, Körn. *Handb. d. Getr.* i. 69 (1885).

One of the most widely cultivated varieties. It is extensively grown in Italy, Spain, and Portugal, the majority of the forms of these countries having long ears (8-10 cm.), which are comparatively lax (D = 24-28) and almost square in section.

It is also found in considerable amount in Asia Minor, but the forms met with in this region have shorter and denser compressed ears, 5-8 cm. long ; D = 34-40 ; oblong in section.

I received lax-eared forms from the Punjab, with ears 9-10 cm. long ; D = 21-23. Some of them are not far removed from the Indian forms of *T. dicoccum.*

1. **Punjab 3.**

Ear, lax, about 10 cm. long, almost square in section, 10-11 mm. across the face and side ; awns somewhat slender, 12-14 cm. long ; spikelets 21-23 ; D = 21-23 (Ear types 1 and 2, Fig. 142).

Empty glume, 11 mm. long, apex blunt, apical tooth short, blunt, secondary nerve distinct, and ending a short distance from the base of the apical tooth (3, Fig. 138).

Grain, flinty, long, and narrow, 9·4 mm. long, 2·6-3 mm. broad, 2·6-3 mm. thick.

2. **Trigo fanfarron.**—Received from Spain.

Young shoots, erect ; young leaves glabrous.

Straw, tall, 125 cm. (about 49 inches) long ; upper internode solid.

1 2

FIG. 141.—MACARONI WHEAT (*T. durum*, Desf.).

1. var. *leucurum*.
(Trigo de espiga larga blanca.)

2. var. *leucurum*.
(Trigo blanquillo.)

Ear, lax, large, 9·5-10 cm. long, square, 11-12 mm. across the sides; spikelets 22-24, 3- to 4-grained; D = 25; awns 10-19 cm. long (Ear type 1, Fig. 141).

Empty glume, 10 mm. long; apical tooth broad, acute, 1 mm. long (7, Fig. 138).

Grain, flinty, 8·5 mm. long, 3·7 mm. broad, 3·4 mm thick.

Closely similar to this are **Trigo de espiga larga blanca, Trigo blanquillo de la Granja de Jeres,** and **Trigo blanco Verdeal** from Spain, and a large form from Abyssinia.

3. **Saragollo.**—Received from Spain and also from Italy; recorded from Sicily by Werner.

Young shoots, erect; young leaves glabrous or slightly rough.

Straw, tall, 124 cm. (about 49 inches) long; upper internode solid.

Ear, narrow, 9-10 cm. long, square, 10-11 mm. across the sides; spikelets 23, 2- to 3-grained; D = 27-29; awns 11-13 cm. long (Ear type 2, Fig. 141).

Empty glume, 9-10 mm. long; apical tooth broad and blunt, ·5 mm. long (11, Fig. 138).

Grain, large, flinty, compressed, with prominent dorsal ridge, 9-9·5 mm. long, 3·6 mm. broad, 4 mm. thick.

4. **Trigo Claro.**—Received from Spain.

Young shoots, erect; young leaves glabrous.

Straw, medium to tall, 114 cm. (about 45 inches) long; upper internode solid.

Ear, 7-8 cm. long, 10-11 mm. across the face, 13 mm. across the side; spikelets 22, 2- to 3-grained; D = 28-32; awns 17 cm. long (Ear type 2, Fig. 143).

Empty glume, 10 mm. long; apical tooth narrow, acute, 1-2 mm. long (8, Fig. 138).

Grain, flinty, 8·6 mm. long, 3·25 broad, 3·55 mm. thick.

Very similar to this is **Duro Catanzaro,** from Italy with narrower and slightly shorter ears.

5. Forms of var. *leucurum* received from Asia Minor are **Ak poussan, Arsus,** and **Alexandretta** wheat, which closely resemble each other.

Ear, moderately lax, 8-10 cm. long, compressed 8-10 mm. across the face, 13-15 mm. across the side; spikelets about 23; awns 12-14 cm. long; D = 25-30 (Ear type 2, Fig. 144).

Empty glume, about 10 mm. long, with stout, acute, apical tooth, 1 mm. long.

Grain, flinty, long, and narrow, 8·5 mm. long, 3 mm. broad, 3 mm. thick.

6. A common form also from Asia Minor, under the names **Menenem Boydesi, Tsirali-ak-Sowsam,** and **Magnesia** wheat, has the following characters:

Ear, dense, compressed, 7-8 cm. long, 9-10 mm. across the face, 14-16 mm. across the side; spikelets 21-23; awns 12-14 cm. long; D = 30-36 (Ear type 2, Fig. 144).

Empty glume, 10 mm. long, 5 mm. wide, apical tooth short, acute (4, 9, Fig. 138).

Grain, semi-flinty, apex narrowed, dorsal ridge prominent; 8-8·5 mm. long, 3·5 mm. broad, 3·5 mm. thick.

7. Short dense-eared forms are also frequent in Asia Minor (Ear type 1, Fig. 145).

Ear, 5-6 cm. long, 8-10 mm. across the face, 13-15 mm. across the side; awns 7-9 cm. long; spikelets 21-23; D = about 40.

Empty glume, 10 mm. long, apical tooth acute.

Grain, flinty, dorsal ridge prominent; 7·5 mm. long, 3·5 mm. broad, 3·3 mm. thick.

8. Derived from an Austrian ear of *T. vulgare*, grown at Reading, is a dense, short-eared form. (? a hybrid with *T. monococcum* grown in an adjacent row.)

Young shoots, erect; young leaves glabrous.

Straw, tall, 127 cm. (about 50 inches) long; upper internode solid.

Ear, short, very dense with narrow face; 5-7 cm. long, 8-10 mm. across the face; D = 43-47; awns 13 cm. long.

Empty glume, 9 mm. long; apical tooth narrow, acute, 1·5-2 mm. long.

Grain, flinty, much compressed laterally, 1·7 mm. long, 2·75-2·8 mm. broad, 3·5 mm. thick.

Ear bearded; glumes white, glabrous; awns white; grain red.

T. durum, var. **affine**, Körn. *Handb. d. Getr.* i. 70 (1885).

A widely distributed variety cultivated in Spain, Portugal, Italy, and North Africa. Found also in small amounts in European Turkey, Russia (the Don Provinces), Transcaucasia, Turkestan, and Asia Minor. I have also had a form of it from Burma.

The majority of the forms have somewhat slender, lax ears about 9 cm. long, and almost square in section; a few possess shorter, denser, compressed ears.

1. The form from Burma is not far removed from forms of *T. dicoccum* and has the following characters:

Ear, narrow, lax, about 8 cm. long, almost square in section, 9-10 mm. across the face and side; spikelets 19-21; D = 23-26; awns 15 cm. long (Ear type 2, Fig. 142).

Empty glume, 11 mm. long, narrow, with acute apical tooth (11, Fig. 138; 2, Fig. 142).

Grain, semi-flinty, small, narrow, about 8 mm. long, 3 mm. wide, 3 mm. thick.

Yiaf boyde from Asia Minor is similar.

2. **Trimenia.**—An ancient and widely distributed form, cultivated in Spain, Portugal, Italy, and North Africa. A form received from Italy under the name **Risciola** is similar, as is also **Trigo Obispado** from Spain.

Young shoots, erect; young leaves glabrous.

Straw, short, 86 cm. (about 34 inches) long; upper internode hollow or solid.

Ear, lax, somewhat slender, 9-10 cm. long, square, 10-12 mm. across the side; spikelets 22-24, 2- to 3-grained; D = 24-26; awns 13-16 cm. long (Ear type 2, Fig. 141).

Empty glume, 9-10 mm. long; apical tooth narrow, acute, 1·5-2 mm. long (6, 9, Fig. 138).

Grain, somewhat short, flinty, dorsal ridge prominent; 7·5-8 mm. long, 3·4 mm. broad, 3·6 mm. thick.

Similar but with longer grain is **De Alfaro** from Spain.

3. **Amarello de barba branca.**—Received from Portugal.

Young shoots, semi-erect; young leaves glabrous.

Straw, slender, of medium height, 110 cm. (about 44 inches) long; upper internode solid.

Ear, 8-10 cm. long, 10-11 mm. across the face, 12-13 mm. across the side; spikelets 21-25, 2- to 3-grained; D=28-30; awns 15-16 cm. long (Ear type 1, Fig. 141).

Empty glume, 11-12 mm. long; apical tooth acute, 1-1·5 mm. long (4, 9, Fig. 138).

Grain, flinty or half mealy, 8·6-9 mm. long, 3·2-3·6 mm. broad, 3·3-3·6 mm. thick.

4. A short, dense-eared form received from Germany, under the name **Sorrentino**; it appears to be near to Körnicke's var. *campylodon* (a form of *affine* with incurved tooth on the empty glume).

Young shoots, erect; young leaves glabrous.

Straw, of medium height, 100 cm. (about 40 inches) high; upper internode solid.

Ear, 6-7 cm. long, square, 12-15 mm. across the sides; spikelets 22-24, 3- to 4-grained; D=33-35; awns 15 cm. long (Ear type 1, Fig. 144).

Empty glume, 10 mm. long; apical tooth short, curved inwards, secondary tooth distinct (4, Fig. 138).

Grain, flinty, 7·9 mm. long, 3·4 mm. broad, 3·7 mm. thick.

5. **Lobeiro.**—Received from Portugal and an allied form from Greece.

Young shoots, semi-erect; young leaves glabrous.

Straw, of medium height, about 96 cm. (about 38 inches) long; upper internode solid.

Ear, dense, compressed, tapering somewhat towards the apex; 8 cm. long, 10-11 mm. across the face, 13-15 mm. across the side; spikelets 20-22, 2- to 3-grained; D=33-35; awns 12-13 cm. long (Ear type 1, Fig. 143).

Empty glume, 10-11 mm. long; apical tooth narrow, acute, 2 mm. long (7, Fig. 138).

Grain, flinty, large, apex truncate, and a somewhat narrow dorsal ridge; 8·6 mm. long, 3·65 mm. broad, 3·55 mm. thick.

Ear bearded; glumes white, glabrous; awns black; grain white.

T. durum, var. **leucomelan**, Körn. *Handb. d. Getr.* i. 70 (1885).

A common Mediterranean variety, especially frequent in Spain and Italy, rare in Russia. Most forms have slightly rough young leaves; they are probably of hybrid origin and related to *T. turgidum* or *T. vulgare*.

The majority possess somewhat short, solid straw; stout, dense, short ears, almost square in section, 7-8 cm. long, 12-15 mm. across the face and side.

The awns are brown or black, and a dark line is usually present along the upper part of the keel and edges of the empty glumes. The latter are large, generally with long, acute, apical teeth.

1. **Trigo Macolo.**—Received from Spain.

Young shoots, erect; young leaves slightly rough.

Straw, of medium height, 100 cm. (about 39 inches) long; upper internode solid.

Ear, 8·5-10 cm. long, square, 12-13 mm. across the side; spikelets 22-24, 2- to 3-grained; D = 29-32; awns 17-18 cm. long (Ear type 2, Fig. 143).

Empty glume, 10-11 mm. long; upper part of apical tooth usually black; apical tooth acute, broad at the base, 1·5-2 mm. long (6, Fig. 138).

Grain, mealy, with truncate apex; 8 mm. long, 3·85 mm. broad, 3·65 mm. thick.

Similar are **Trigo de espiga azulada** and **Trigo Alonso** from Spain; in these the empty glume has a narrow, longer, apical tooth.

2. **Trigo Chacon.**—Received from Spain.

Young shoots, erect; young leaves glabrous.

Straw, of medium height, 110-115 cm. (about 40-42 inches) high; upper internode solid.

Ear, coarse, stout, short, and dense, 6-8 cm. long, square, 15 mm. across the sides; spikelets broad, 20-22, 3- to 4-grained; D = 30-32; awns stout, 13-14 cm. long (Ear type 1, Fig. 143).

Empty glume, 11-12 mm. long; apical tooth acute, 2 mm. long (4, Fig. 138).

Grain, large, semi-flinty, 8·8-9 mm. long, 3·8-3·9 mm. broad, 4 mm. thick.

Very similar is **Trigo Cannu altu** from Spain and Italy.

3. **T. raspinegro de espiga pequeña.**—Received from Spain.

Young shoots, semi-erect; young leaves with few short hairs.

Straw, of medium height, 102 cm. (about 40 inches) long; upper internode solid.

Ear, short, dense, often convex on one side; 6-6·5 cm. long, 10 mm. across the face, 17 mm. across the side; spikelets 23-24, 2- to 3-grained; D = 44; awns 13-14 cm. long (Ear type 1, Fig. 145).

Empty glume, 10 mm. long; apical tooth narrow, acute, 2 mm. long (6, Fig. 138).

Grain, flinty, 8·7 mm. long, 3·85 mm. broad, 3·6 mm. thick.

Ear bearded; glumes white, glabrous; awns black; grain red.

T. durum, var. Reichenbachii, Körn. *Handb. d. Getr.* i. 70 (1885).

First obtained by Körnicke from the Dresden Botanic Garden as "*Triticum meianocus*" (? *melanocus*), and later from the Province of Cadiz in Spain.

A somewhat uncommon variety received from Spain, Greece, and Asia Minor; Flaksberger mentions its rare occurrence in Russia (the Don Provinces and Caucasus) and in Turkestan.

1. **Trigo raspinegro.**—Received from Spain.

Young shoots, erect; young leaves slightly rough.

1 2

FIG. 142.—MACARONI WHEAT (*T. durum*, Desf.).

1. var. *Reichenbachii*. (Greece.)

2. var. *affine*. (Burma.)

Straw, very tall, 127 cm. (about 59 inches) long ; upper internode solid.

Ear, 8-9 cm. long, coarse, square, 11-12 mm. across the sides, or compressed, and 10 mm. across the face, 12-13 mm. across the side ; spikelets 20-24, 2- to 3-grained ; D=25-28 ; awns stout, 17-18 cm. long, sometimes irregularly bent (Ear type 2, Fig. 143).

Empty glume, 10-12 mm. long, narrow ; apical tooth small, about 1 mm. long (4, Fig. 138).

Grain, flinty, long, and narrow, apex truncate ; 8-9 mm. long, 3·3 mm. broad, 3·85 mm. thick.

Grano forte from Italy resembles this form.

A larger form with square ears, 12-13 mm. across the sides and paler awns, also from Spain.

2. **Trigo marzuolo.**—Received from Italy, and similar forms from Greece.

Young shoots, erect ; young leaves glabrous.

Straw, tall, 116 cm. (about 46 inches) long ; upper internode hollow.

Ear, long and narrow, 8-10 cm. long, square, 10-11 mm. across the sides ; spikelets 23, 2- to 3-grained ; D=23-26 ; awns 14 cm. long (Ear type 1, Fig. 142).

Empty glume, narrow, 11 mm. long ; apical tooth 1-2 mm. long, acute, usually with a black margin (9, Fig. 138).

Grain, flinty, with truncate apex and narrow dorsal ridge ; 8 mm. long, 3·45 mm. broad, and 3·6 mm. thick.

I received a smaller form allied to this from Adana, Asia Minor, under the name **Yerli.**

Ear bearded ; glumes white, pubescent ; awns white ; grain white.

T. durum, var. **Valenciae**, Körn. *Handb. d. Getr.* i. 72 (1885).

Körnicke received this variety from Valencia, Spain, the Government of Kharkov, Russia, and Chili.

I have received it from Austria, Bulgaria, Asia Minor (Damascus), and the Punjab, India ; also in samples of Goose wheat from Canada.

Forms of this variety are rare and liable to be confused with examples of the black-awned var. *melanopus*, in which the dark pigment does not develop in some seasons.

Flaksberger says that the forms from Russia should be placed under the variety *melanopus*.

1. **Trigo Siciliani.**—Received from Italy.

Young shoots, semi-erect ; young leaves glabrous.

Straw, tall, 116 cm. (about 46 inches) high ; upper internode solid.

Ear, 9 cm. long, square, 10-12 mm. across the sides, or compressed, and 10-11 across the face, 12-14 mm. across the side ; spikelets 21-23, 2- to 3-grained ; D=28-30 ; awns 13 cm. long (Ear type 1, Fig. 142).

Empty glume, 9-11 mm. long, 4 mm. broad ; apical tooth 1-1·5 mm. long (12, 13, Fig. 138).

Grain, flinty, apex narrowed ; 8-8·5 mm. long, 3·1-3·5 mm. broad. Similar to this is **Beloklassa zagani** from Bulgaria.

2. **Cawnpore 2.**

Ear, large, 10 mm. long, compressed 10 mm. across the face, 13-14 mm. across the side; spikelets 22-24; D=23-26 (Ear type 1, Fig. 141).

Empty glume, large, 12 mm. long, 5 mm. broad, apex broad, apical tooth short and blunt (2, Fig. 138).

Grain, long and narrow, 8 mm. long, 3 mm. wide, 3 mm. thick.

3. **Cawnpore 9.**—Somewhat similar to the previous form but with smaller, denser ears.

Ear, about 9 mm. long, 10 mm. square, or 9 mm. across the face, and 11 mm. across the side; spikelets 21-23; D=28 (Ear type 2, Fig. 141).

4. A form of var. *Valenciae* received from Damascus, Asia Minor, under the name **Yabroudi Bayadi**, has the following characters:

Ear, compressed, 8 cm. long, 6-8 mm. across the face, 11-13 mm. across the side; spikelets 22-27; D=30-36.

Empty glume, 8·5 mm. long, 3 mm. broad, apical tooth acute, short (1, 11, Fig. 138).

Grain, 7·5 mm. long, 3-3·4 mm. broad, 2·5-3 mm. thick.

Ear bearded; glumes white, pubescent; awns white; grain red.

T. durum, var. fastuosum, Körn. *Handb. d. Getr.* i. 72 (1885).

A rare variety received by Körnicke from the Government of Kharkov, Russia, and from an Exhibition in Vienna in 1873. Flaksberger states that he has not seen a single ear of this variety from any part of the Russian Empire.

I have received specimens only from India (Central and United Provinces). These were narrow lax-eared forms with the following characters:

Young shoots, erect; young leaves glabrous.

Straw, of medium height, 104 cm. (about 41 inches) long; upper internode almost solid.

Ear, small, narrow, 7-9·5 mm. long, square, 10-11 mm. across the sides or slightly compressed, 8-9 mm. across the face, and 11-12 mm. across the side; spikelets 21-23, 3-grained; D=25-27; awns slender, 10-13 cm. long (Ear types 1, 2, Fig. 142).

Empty glume, 9 mm. long, apical tooth short and blunt, ·5 mm. long (10, Fig. 138).

Grain, flinty, apex narrow, 7·5-8·5 mm. long, 3·2 mm. broad, 3·5 mm thick.

Ear bearded; glumes white, pubescent; awns black; grain white.

T. durum, var. melanopus, Körn. *Handb. d. Getr.* i. 72 (1885).

One of the commonest varieties of *T. durum* with a wide distribution, being cultivated in Spain, Portugal, Italy, Roumania, South-East Russia, Turkestan, Siberia, Asia Minor, and India.

Forms of this variety are found with long and somewhat narrow, square ears 10 mm. across; the majority, however, have short, broad ears, 14-15 mm. square, strong coarse awns, and slightly scabrid young leaves.

The forms from Asia Minor generally possess short, dense, compressed ears and stout awns. The ears are usually from 5·5 to 7·5 cm. long, 10-12 mm. across the face, and 14-15 mm. across the side; D = usually about 33, but the density of the shortest ears sometimes reaches 40.

Narrow-eared forms received from Russia and Dobrudja, Roumania, with pale brown awns, have the following characters:

Young shoots, erect; young leaves glabrous or slightly hairy.

Straw, slender, tall, 118 cm. (about 47 inches) long; upper internode hollow.

Ear, slender, 9 cm. long, square, 10-11 mm. across the sides; spikelets 25-27, 2- to 3-grained; D = 31-32; awns slender, 12-13 cm. long (Ear type 1, Fig. 142).

Empty glume, short, and somewhat inflated, 8 mm. long; apical tooth short, broad at the base, 1-1·5 mm. long (18, 19, Fig. 138).

Grain, flinty, small, 7 mm. long, 3·55 mm. broad, 3·2 mm. thick.

1. **Punjab 1.**

Young shoots, erect; young leaves glabrous.

Straw, tall, to very tall, 132 cm. (about 53 inches) high; upper internode hollow.

Ear, 9-10 cm. long, almost square, 11-12 mm. across the sides; spikelets 22-26, 2- to 3-grained; D = 27-28; awns stout, 12-16 cm. long, jet black or sometimes pale brown (Ear types 1, Fig. 141; 2, Fig. 143).

Empty glume, 10 mm. long; apical tooth, short and bluntish, about 1 mm. long (1, 2, Fig. 138).

Grain, small, flinty, apex blunt, 7·3-7·5 mm. long, 3·4 mm. broad, 3·1 mm. thick.

I received a similar form from Bombay, the Shan States, Northern Burma, and other parts of India; also from Asia Minor.

2. **Durazio mollar.**—Received from Portugal.

Young shoots, semi-erect; young leaves slightly rough.

Straw, somewhat slender, tall, 116 cm. (46 inches) high; upper internode solid.

Ear, short, 6-8 cm. long, square, 10-12 mm. across the sides or slightly compressed, 10 mm. across the face, and 11-12 across the side; spikelets 21, 3-grained; D = 33; awns 14-15 cm. long, sometimes pale brown (Ear type 2, Fig. 143).

Empty glume, 10 mm. long; apical tooth narrow, acute, 1·5-2 mm. long (Form 6, Fig. 138).

Grain, semi-flinty, compressed, with high and narrow dorsal ridge; 8·25 mm. long, 3·75 mm. broad, 3·6 mm. thick.

Zwaart Baard from South Africa resembles this.

Durazio rijo from Estramadura, Portugal, is also similar with somewhat longer ears and larger, yellowish-white grain.

3. **Trigo Andaluze.**—Received from Spain and a similar form from Algeria.

Young shoots, erect; young leaves glabrous.

Straw, of medium height, 102 cm. (about 40 inches) long; upper internode solid.

Ear, stout and coarse, 8-9 mm. long, square, 13-15 mm. across the sides; spikelets 20-22, 3- to 4-grained; D = 28-32; awns strong, black, 15-16 cm. long (Ear type 2, Fig. 143).

Empty glume, 10-11 mm. long; apical tooth acute, 1·5-2 mm. long (Form 9, Fig. 138).

Grain, flinty, long, narrow, 8·7-9 mm. long, 4·0 mm. broad, 4·0 mm. thick.

Goose from Canada resembles this, but has smaller, narrower ears.

4. Similar forms from Spain are **Trigo Macolo, T. negro,** with glabrous leaves, and **T. Enano de Larco, Trigo Recio de Granada, T. Granadino** and others with slightly scabrid young leaves.

Forms with shorter and denser ears (7 cm. long, 15 mm. across the sides, D=33-36), and shorter grain, are also met with in Spain under various names.

Ear bearded; glumes white, pubescent; awns black; grain red.

T. durum, var. **africanum,** Körn. *Handb. d. Getr.* i. 73 (1885).

Körnicke obtained this variety from Portugal, Egypt, and Asia Minor.

A somewhat rare variety received from Spain, Portugal, Russia, and India.

The Russian and Indian forms have long, somewhat narrow, square ears (D=27-32), those from Spain and Portugal large, coarse, denser ears, showing affinity with *T. turgidum*.

1. **Alexandre.**—Received from Portugal; cultivated in Santa Cruz, Funchal.

Young shoots, erect; young leaves glabrous.

Straw, of medium height, 109 cm. (about 43 inches) long; upper internode solid.

Ear, stout, 6-8 cm. long, square, 12-14 mm. across the sides; spikelets 22-23, 3-grained; D=31; awns 16-18 cm. long (Ear type 1, Fig. 143).

Empty glume, 10-11 mm.; apical tooth very long and narrow, 4-5 mm. long (6, 7, Fig. 138).

Grain, flinty, large, 8·3-8·7 mm. long, 3·2-3·4 mm. broad, 3·3-4·1 mm. thick.

2. **Russian Form.**

Young shoots, semi-erect; young leaves slightly rough.

Straw, somewhat slender, very tall, 140 cm. (about 55 inches) high; upper internode hollow.

Ear, 7·5-8 cm. long, square, 10-11 mm. across the sides; spikelets 22, 3-grained; D=32; awns 15 cm. long (Ear type 2, Fig. 143).

Empty glume, 9 mm. long; apical tooth short, broad, and blunt, 1 mm. long (11, Fig. 138).

Grain, flinty, short, with narrow dorsal ridge; apex truncate; 7·1 mm. long, 3·6 mm. broad, 3·8 mm. thick.

3. **Anafil.**—Received from Portugal.

Young shoots, erect; young leaves slightly rough.

Straw, slender, tall, 130 cm. (about 51 inches) long; upper internode solid.

Ear, dense, often broad at the base and tapering towards the apex, 8-9 cm. long, 12 mm. across the face, 15-18 mm. across the side; spikelets 27-29, 3- to 4-grained; D=36; awns 14-15 cm. long (Ear type 2, Fig. 144).

Empty glume, 10 mm. long; apical tooth acute, 2·5-3 mm. long (5, Fig. 138).

FIG. 143.—MACARONI WHEAT (*T. durum*, Desf.).

1. var. *leucomelan*. (Alonso o Fanfarron.)

2. var. *leucomelan*. (Trigo Macolo.)

Grain, flinty, with prominent dorsal ridge, 8·5 mm. long, 3·3 mm. broad, 3·6 mm. thick.

4. **Punjab 2.**

Straw, of medium height, 77-97 cm. (36-38 inches) high.

Ear, long, lax, compressed, 8-10 cm. long, 8-10 mm. across the face, 12 mm. across the side; spikelets 22-24; D = 30-34; awns 14-15 cm. long (Ear types: 1, Fig. 141; 2, Fig. 143).

Empty glume, 8-9 mm. long, 4 mm. broad, with short, blunt, apical tooth (Form 12, Fig. 138).

Grain, long, narrow, flinty, with prominent, dorsal ridge; 8·3 mm. long, 3·3 mm. broad, 3·2 mm. thick.

In some seasons this form has pale awns and is then confused with var. *fastuosum*.

Ear bearded; glumes red, glabrous; awns red; grain white.

T. durum, var. **hordeiforme**, Körn. *Handb. d. Getr.* i. 71 (1885).

One of the most widely distributed varieties of *T. durum*, especially common in Russia, Bulgaria, Turkey, Greece, and Asia Minor. It occurs also in India, Egypt, the North African Coast, Italy, Spain, and Portugal, but is rare in the three latter countries.

The Macaroni Wheats usually grown in the United States belong to this variety.

Four general types of ear are found, namely:

a. An elongated, narrow form about 10 cm. long, square in section, about 10 mm. across the sides; awns 15-18 cm. long (2, Fig. 141).

b. A similar form with ears 7-8 cm. long; awns 15-18 cm. long, and stout (2, Fig. 142).

c. A shorter, denser form, 7-9 cm. long, square in section, 10-12 mm. across the sides; awns 13-15 cm. long (Figs. 143, 144).

d. A short, much compressed form, 6-8 cm. long, 8-10 mm. across the face, and 15-20 mm. across the side; awns 12-14 cm. long (2, Fig. 144).

1. Most of the "Kathias" of India are forms with narrow ears, stout, very long awns (Ear type 2, Fig. 142), and narrow, strongly keeled, empty glumes (11, Fig. 138, and 2, Fig. 142). The upper internodes are almost solid. They are not far removed from the Indian *T. dicoccum*.

2. Several spring forms received from Spain and Portugal and showing affinities with *T. vulgare* or *T. turgidum* have the following characters:

Young shoots, erect; young leaves more or less hairy.

Straw, of medium height, 45-100 cm. (38-40 inches) high; upper internode solid or hollow with thick walls.

Ear, long, lax, and narrow, 10-12 cm. long, square, 10-11 mm. across the sides; spikelets 24-27, 3-grained; D = 24-26; awns 12-14 cm. long (Ear type 2, Fig. 141).

Empty glume, short and somewhat inflated, 8 mm. long; apical tooth ·5-1 mm. long (11, Fig. 138).

Grain, semi-flinty, with high dorsal ridge; 8-8·3 mm. long, 3·3-3·6 mm. broad, 3·6-3·85 mm. thick.

3. **Kubanka.**—This is the common form of var. *hordeiforme* grown in the Kuban territory, South Russia, and now introduced into most countries where Macaroni Wheats are cultivated; most Russian **Arnautka** forms are similar to this.

Young shoots, semi-erect or prostrate; young leaves glabrous.

Straw, very tall, 140 cm. (about 55 inches) long; upper internode hollow.

Ear, lax, 9-10 cm. long, square 10-11 mm. across the sides; spikelets 24, 2- to 3-grained; D=24-27; awns 13-15 cm. long (Ear type 1, Fig. 142).

Empty glume, 9 mm. long; apical tooth acute, 1-1·5 mm. long (10, Fig. 138).

Grain, flinty, sometimes opaque, 7·5-8 mm. long, 3·6 mm. broad, 3·4-3·6 mm. thick.

4. **Bieloturka** (=White Turkish).—Autumn or spring forms received from Russia, Greece, Turkey, and Spain; these closely resemble the forms named **Kubanka**, but have shorter and somewhat denser ears.

Young shoots, semi-erect; young leaves glabrous.

Straw, of medium height, 95-100 cm. (38-40 inches) high; upper internode hollow, with thick walls.

Ear, 6-8 cm. long, often tapered towards the apex, square, 10-12 mm. across the sides; spikelets 22-25, 3-grained; D=29-32; awns 12-14 cm. long (Ear type 1, Fig. 144).

Empty glume, 8-9 mm. long, apical tooth broad and blunt, 1 mm. long (11, Fig. 138).

Grain, flinty or semi-flinty, usually plump with bluntish apex; 7·6 mm. long, 3·5 mm. broad, 3·3 mm. thick.

Several forms, chiefly received from Russia under the names **Bieloturka** and **Arnovka**, possess rough or slightly pubescent leaves and suggest a relationship with *T. turgidum* or *T. vulgare*.

5. Spring form received from Russia and Greece and from Spain under the name **Bieloturka**. Slightly taller than the previous winter form, with denser ears (D=33-36).

6. Forms from Turkey and Asia Minor under the names **Sari Bashak**, **Sari Sakij**, and **Kizil Bogdai** have the following characters:

Ear, short, dense, compressed, 6-7·5 cm. long, 6-9 mm. across the face, 14-16 mm. across the side; spikelets 20-25; D=33-36; awns 12-14 cm. long (Ear type 2, Fig. 144).

Empty glume, about 10 mm. long, flattened, with acute, apical tooth (8, Fig. 138).

Grain, flinty, long, and narrow, 7·5-8 mm. long, 2·5-3 mm. broad, 2·5-3 mm. thick.

Ear bearded; glumes red, glabrous; awns red; grain red.

T. durum, var. **murciense**, Körn. *Handb. d. Getr.* i. 71 (1885).

Körnicke records this variety from Spain (Murcia), Portugal, Persia, Altai, and Egypt.

Flaksberger mentions the occurrence of dense-eared forms in Turkestan and the Russian provinces of Kuban and Samara.

I have had examples from Portugal, Bulgaria, Greece, Asia Minor, and Burma.

A widely distributed but somewhat rare variety, the chief forms of which have long, narrow ears, 8-10 cm. square in section. A few are found in the eastern Mediterranean region with denser, shorter, and somewhat compressed ears.

1. Forms received from Bulgaria, Turkey, Greece, and Jaffa have the following characters :

Young shoots, semi-erect ; young leaves slightly rough.

Straw, tall to very tall, 132 cm. (about 53 inches) long ; upper internode hollow.

Ear, 8-10 cm. long, square, 10 mm. across the sides; spikelets 23-27, 3-grained ; D = 29-31 ; awns 13-14 cm. long (Ear type 2, Fig. 141).

Empty glume, 9-10 mm. long ; apical tooth narrow, acute, 1 mm. long (14, Fig. 138).

Grain, flinty, apex blunt, 7·65 mm. long, 3·15 mm. broad, 3·5 mm. thick.

2. **Santa Marta.**—Received from Portugal.

Young shoots, erect ; young leaves slightly rough, old leaves glabrous.

Straw, tall, 110 cm. (about 43 inches) high ; upper internode solid.

Ear, lax, 8-10 cm. long, square, 10-11 mm. across the sides ; spikelets 19-22, 3-grained ; D = 24-25 ; awns 14 cm. long (Ear type 1, Fig. 142).

Empty glume, 10 mm. long ; apical tooth narrow, acute, about 1 mm. long (6, Fig. 138).

Grain, flinty, with truncate apex ; 8·3 mm. long, 3·7 mm. broad, 3·7 mm. thick.

A form of *hordeiforme* is also found under this name in Portugal.

3. Received from Greece.

Young shoots, erect ; young leaves glabrous.

Straw, tall, 127 cm. (about 50 inches) high ; upper internode solid.

Ear, short and flat, 7-8 cm. long, 8-9 mm. across face, 12 mm. across side ; spikelets 22, 2- to 3-grained ; D = 29-32 ; awns slender, 12 cm. long (Ear type 2, Fig. 143).

Empty glume, 9 mm. long ; apical tooth short, broad at base, ·5-1 mm. long (10, Fig. 138).

Grain, flinty, with truncate apex, 8·2 mm. long, 3·7 mm. broad, 3·95 thick.

Ear bearded ; glumes red, glabrous ; awns black ; grain white.

T. durum, var. **erythromelan**, Körn. *Handb. d. Getr.* i. 71 (1885).

Körnicke received this variety from Murcia, Spain. It is chiefly found in Spain and Portugal ; very rare in Russia.

1. **Medea** or **Trigo raspinegro de Medea.**—Received from Spain.

Young shoots semi-erect ; young leaves glabrous.

Straw, of medium height, 106 cm. (about 42 inches) high, upper internode solid.

Ear, lax and square, 9-10 cm. long, 10-11 mm. across the sides ; spikelets 22, 3-grained ; D=25-26 ; awns 17-18 cm. long, their bases jet black (Ear type 1, Fig. 142).

Empty glume, 10 mm. long ; apical tooth acute, 1 mm. long (6, 9, Fig. 138).

Grain, semi-flinty, 8 mm. long, 3·7 mm. broad, 3·6 thick.

2. **Russian Form.**

Young shoots, semi-erect ; young leaves glabrous.

Straw, short, 90 cm. (about 35 inches) high ; upper internode hollow.

Ear, lax, 8-9 cm. long, square, 10 mm. across the sides ; spikelets 20-22, 2- to 3-grained ; D=27 ; awns 15 cm. long (Ear type 1, Fig. 142).

Empty glume, 9 mm. long ; apical tooth acute, 1 mm. long (8, Fig. 138).

Grain, flinty, dorsal ridge prominent, 7·7 mm. long, 3·4 mm. broad, 3·2 mm. thick.

Similar forms from Spain.

3. **Trigo pinot** and others received from Spain.

Young shoots, erect ; young leaves glabrous.

Straw, tall, 140 cm. (55 inches) high ; upper internode solid.

Ear, dense, 6·5-8 cm. long, square, 10-13 mm. across the side or compressed, 9 mm. across the face, and 11-12 mm. across the side ; spikelets 21-23, 3- to 4-grained ; D=32-35 ; awns 15 cm. long (Ear type 1, Fig. 144).

Empty glume, 9-10 mm. long ; apical tooth short, acute, 1 mm. long (5, 7, Fig. 138).

Grain, flinty, 8 mm. long, 3·8 mm. broad, 3·75 mm. thick.

Trigo Colorado, Trigo berberisco, and others from Spain are similar to this form.

4. **Trigo bascuñano** and others from Spain, and **Mourisco vermelho** from Portugal.

Young shoots, semi-erect ; young leaves glabrous.

Straw, tall, 130 cm. (about 51 inches) long ; upper internode solid.

Ear, short, dense, and tapering towards the apex ; 5-7 cm. long, 10 mm. across the face, 13-15 mm. across the sides ; spikelets 20-23, 2- to 3-grained ; D=37-40 ; awns 13-15 cm. long (Ear type 2, Fig. 144).

Empty glume, 9-10 mm. long ; apical tooth broad and bluntish, 1-1·5 mm. long (9, 11, Fig. 138).

Grain, flinty, with high dorsal ridge ; 8-8·2 mm. long, 3·1-3·4 mm. broad, 3·6-3·8 mm. thick.

5. A form from Alexandretta, Asia Minor, has the following characters :

Ear, short, compressed, 6-7 cm. long, 8-9 mm. across the face, 13-14 mm. across the side ; spikelets 20 ; D=35 ; awns stout, jet black, about 14 cm. long (Ear type 2, Fig. 144).

1 2

FIG. 144.—MACARONI WHEAT (*T. durum*, Desf.).

1. var. *affine*. (Sorrentino.)

2. var. *alexandrinum*. (Canary Isles.)

Empty glume, oval, very broad, 9 mm. long, 4 mm. wide (9, 12, Fig. 138).
Grain, flinty, 7-7·5 mm. long, 3 mm. broad, 3 mm. thick.

Ear bearded ; glumes red, glabrous ; awns black ; grain red.

T. durum, var. **alexandrinum**, Körn. *Handb. d. Getr.* i. 71 (1885).

Körnicke's type was obtained from Lower Egypt through L. Wittmack. A comparatively rare variety which I have received only from Spain and the Canary Isles.

1. **Trigo bascuñano** from Spain.

Young shoots, erect ; young leaves glabrous or slightly rough.

Straw, tall, 127 cm. (50 inches) high ; upper internode solid.

Ear, dense, 7-8 cm. long, 10-12 mm. across the face, 13-16 mm. across the side ; spikelets 22-23, 2- to 3-grained ; D = 33-35 ; awns 15-17 cm. long (Ear type 1, Fig. 144).

Empty glume, 9-10 mm. long ; apical tooth slightly curved, acute, 1 mm. long (9, Fig. 138).

Grain, semi-flinty, 8·25 mm. long, 3·65 mm. broad, 3·8 mm. thick.

Allied to this are short-eared forms from the Canary Isles and a long-eared form (ears 9-10 cm. long and D = 28-30).

2. **Spanish Form.**

Young shoots, erect ;. young leaves glabrous or slightly rough.

Straw, of medium height, 90 cm. (about 35 inches) high ; upper internode hollow.

Ear, short, dense, 6-8 cm. long, square, 10-12 mm. across the sides or slightly compressed ; spikelets 20-24, 3- to 4-grained ; D = 30 ; awns divergent, 12-13 cm. long (Ear type 1, Fig. 144).

Empty glume, 9-10 mm. long, keel and outer edge often black ; apical tooth acute, 1·5-2 mm. long (9, Fig. 138).

Grain, flinty, 8 mm. long, 3-3·5 mm. broad, 3-3·5 mm. thick.

Ear bearded ; glumes red, pubescent ; awns red ; grain white.

T. durum, var. **italicum**, Körn. *Handb. d. Getr.* i. 73 (1885).

Körnicke obtained this variety from Italy, Spain (Murcia and Valencia), Greece, and Egypt.

Forms of var. *apulicum* in some seasons do not develop the black colour in the awns and may often be placed under this variety. All the forms I have seen of this variety exhibit characters which suggest affinity with *T. turgidum* or *T. vulgare*.

Trigo Siciliani.—Received from Italy.

This form is not typical of *T. durum* ; the characters of leaves, ears, straw, and grain suggest an affinity with *T. turgidum*.

Young shoots, semi-erect ; young leaves pubescent.

Straw, of medium height, 90 cm. (about 36 inches) high ; upper internode solid.

Ear, large, 9-11 cm. long, square, 11-13 mm. across the sides ; spikelets

25-26, 3- to 4-grained; D = 23-26; awns stout, 15 cm. long, somewhat divergent (Ear type 1, Fig. 141).

Empty glume, 10 mm. long; apical tooth 3 mm. long; secondary notch distinct (4, Fig. 138).

Grain, very large, flinty, 10 mm. long, 3·9 mm. broad, 4 mm. thick.

A similar but smaller form, with ears 6-8 cm. long (D = 30-35), was received from Italy under this name.

Ear bearded; glumes red, pubescent; awns red; grain red.

T. durum, var. **aegyptiacum**, Körn. *Handb. d. Getr.* i. 73 (1885).

Körnicke obtained this variety from Egypt, Apulia, and the Government of Kharkov, Russia.

Vermelho fino.—A form showing affinities with *T. turgidum* or *T. vulgare* received from Portugal.

Young shoots, semi-erect; young leaves with a few hairs.

Straw, of medium height, 90 cm. (about 36 inches) high; upper internode hollow with thick walls.

Ear, 7-9 cm. long, square, 10-14 mm. across the sides; spikelets 19-22, 3-grained; D = 26-27; awns 15-17 cm. long, somewhat divergent (Ear type 1, Fig. 143).

Empty glume, 11-12 mm. long; apical tooth short, blunt, ·5-1 mm. long (18, 19, Fig. 138).

Grain, very long, pale red, flinty, 10 mm. long, 3·5 mm. broad, 3·5 mm. thick.

Ear bearded; glumes red, pubescent; awns black; grain white.

T. durum, var. **apulicum**, Körn. *Handb. d. Getr.* i. 73 (1885).

Körnicke obtained forms of this variety with lax and dense ears from Apulia (Italy), Andalusia (Spain), and a dense-eared form from Lower Egypt.

Flaksberger states that a lax-eared spring form and a dense-eared winter form of this variety are cultivated in the Transcaucasus. I received a form with long, lax, narrow ears from the United Provinces, India, and one with short dense ears from Spain.

Cawnpore 18.—Indian form.

Ear, long, lax, and narrow, almost square in section, 8-9 cm. long, 9-10 mm. across the sides; spikelets 22-24; D = 28-32; awns 11-13 cm. long (Ear types 1, 2, Fig. 142).

Empty glume, short, 8 mm. long; apical tooth stout (8, 10, Fig. 138).

Grain, flinty, small, 7·7 mm. long, 3·1 mm. broad, 3 mm. thick.

Ear bearded; glumes red, pubescent; awns black; grain red.

T. durum, var. **niloticum**, Körn. *Handb. d. Getr.* i. 73 (1885).

Körnicke obtained dense-eared specimens of this variety from Upper Egypt and Apulia, Italy.

Flaksberger records isolated ears from Russia (the Don Provinces), and I have had it from Asia Minor. Some of the forms I have seen of this variety

FIG. 145.—MACARONI WHEAT (*T. durum*, Desf.).

1. var. *leucomelan*.
(Trigo raspinegro de espiga pequeña.)

2. var. *niloticum*.
(A dense eared Spanish form.)

show affinities with *T. turgidum* or *T. vulgare*. The ears are chiefly of two types: (1) very long, lax, and square in section, and (2) short, dense, compressed ears.

1. A form from Spain, showing affinities with *T. vulgare*.

Young shoots, semi-erect; young leaves slightly pubescent.

Straw, of medium height, 95-100 cm. (about 36-38 inches) high; upper internode hollow.

Ear, 8-10 cm. long, square, 10-12 mm. across the sides; spikelets 22-25, 3-grained; D=25-27; awns 13-14 cm. long (Ear type 1, Fig. 142).

Empty glume, 8-10 mm. long; apical tooth acute, 1·5-2 mm. long (5, Fig. 138).

Grain, pale red, flinty, 7·5-8·5 mm. long, 3·3 mm. broad, 3·4 mm. thick.

2. **Spanish Form.**

Young shoots, semi-erect; young leaves glabrous.

Straw, of medium height, 95-100 cm. (38-40 inches) high; upper internode solid.

Ear, short and dense, 6 cm. long, compressed, 13-14 mm. across the face, 17-20 mm. across the sides; spikelets 21, 3- to 4-grained; D=38; awns 15-16 cm. long (Ear type 2, Fig. 145).

Empty glume, 10-11 mm. long; apical tooth narrow, 1·5-2 mm. long (4, Fig. 138).

Grain, flinty, long, and pointed at the apex, 9·4 mm. long, 3·3 mm. broad, 3·8 mm. thick.

Ear bearded; glumes blue-black, glabrous; grain white.

T. durum, var. **provinciale**, Körn. *Handb. d. Getr.* i. 71 (1885).

In some seasons the glumes are a dark reddish tint.

A comparatively rare variety received from Spain and Morocco, and recorded by Flaksberger as of casual occurrence in South Russia.

Spanish Form.

Young shoots, erect; young leaves glabrous.

Straw, tall, 135 cm. (about 53 inches) high; upper internode hollow.

Ear, somewhat lax, 9 cm. long, square, 12-14 mm. across the sides; spikelets 23, 3- to 4-grained; D=27; awns 15-17 cm. long (Ear type 2, Fig. 141).

Empty glume, 10-11 mm. long; apical tooth narrow, acute, ·5-1 mm. long (4, Fig. 138).

Grain, flinty, with high dorsal ridge and blunt apex; 8·25 mm. long, 3·65 mm. broad, 3·8 mm. thick.

Ear bearded; glumes blue-black, glabrous; grain red.

T. durum, var. **obscurum**, Körn. *Handb. d. Getr.* i. 72 (1885).

A rare variety received by Körnicke from Spain.

Ear bearded; glumes blue-black, pubescent; grain white.

T. durum, var. **coerulescens**, Körn. *Handb. d. Getr.* i. 73 (1885).

The hairs on the glumes are usually few and inconspicuous. In some seasons

the empty glumes of most forms are dark reddish tint with a black stripe along the outer margins. Körnicke obtained samples of this variety from Spain, Italy, Upper Egypt, and Chili.

Flaksberger records its occurrence in S. and S.E. Russia, Transcaucasia, Siberia, and Turkestan, and Asia Minor, Turkey (Adrianople).

I have had specimens from Russia.

1. Received from Semipalatinsk, Russia, and in commercial " Hard Taganrog."

Young shoots, erect ; young leaves glabrous.

Straw, tall, slender, 132 cm. (about 52 inches) long ; upper internode hollow.

Ear, lax and square, 8-9 cm. long, 10-12 mm. across the sides ; spikelets 20-23, 3- to 4-grained ; D = 26-28 ; awns 14-15 cm. long (Ear type 1, Fig. 142).

Empty glumes, 10-11 mm. long ; apical tooth narrow, acute, 1-1·5 mm. long (8, 11, Fig. 138).

Grain, flinty, with narrow apex, 8·5 mm. long, 3·5 mm. broad, 3·5 mm. thick.

2. **Kara Bashak** from Adrianople and **Arab boydé** from Asia Minor are forms of *coerulescens* with compressed ears, 6-7 cm. long (Ear type 2, Fig. 144).

Ear bearded ; glumes blue-black, pubescent ; grain red.

T. durum, var. **libycum**, Körn. *Handb. d. Getr.* i. 73 (1885).

The glumes are only slightly pubescent, and the hairs easily overlooked as in the previous variety.

Körnicke's type was collected by P. Ascherson in the oasis Merdisheh in the Libyan Desert (1876) ; the native name is "Tuêdi."

Flaksberger records the rare occurrence of var. *libycum* in the Samara Province, Russia.

I have received forms of it from Morocco, Spain, Portugal, and Bulgaria.

1. **Morocco Form.**

Young shoots, erect ; young leaves glabrous.

Straw, of medium height, 106 cm. (about 42 inches) long ; upper internode solid.

Ear, 7-8 cm. long, square, 11-13 mm. across the sides ; spikelets 17-20, 3- to 4-grained ; D = 28-30 ; awns stout and very long, some of them reaching a length of 23 cm. (Ear type 2, Fig. 138).

Empty glume, 11-13 mm. long ; apical tooth acute, curved, 1·2 mm. long (4, Fig. 138).

Grain, flinty, 8·2-8·6 mm. long, 3-3·4 mm. broad, 3-3·4 mm. thick.

2. **Madonna.**—Received from Haage and Schmidt, Erfurt, Germany.

Young shoots, semi-erect ; young leaves glabrous.

Straw, very tall, 150 cm. (about 60 inches) high ; upper internode hollow with thick pithy walls.

Ear, dense, 7-8 cm. long, square, 11-13 mm. across the sides, or compressed, 10-12 mm. across the face, and 14-15 mm. across the side ; spikelets 26, 3- to 4-grained ; D = 33-34 ; awns 15-17 cm. long (Ear type 2, Fig. 143).

1 2

FIG. 146.—MACARONI WHEAT (*T. durum*, Desf.).

1. var. *affine*. (Asia Minor.)

2. var. *australe*. (Huguenot.)

Empty glume, 9 mm. long; apical tooth 2-3 mm. long, the tip sometimes curved outwards (5, Fig. 138).

Grain, flinty, small, with high dorsal ridge, 7·1 mm. long, 3·15 mm. broad, 3·4 mm. thick.

Javardo from Portugal is similar, but in some seasons the empty glumes are reddish or yellowish with black keels and edges.

3. **Trigo raspinegro espiga negra.**—Received from Spain.

Young shoots, erect; young leaves glabrous.

Straw, of medium height to tall, 135 cm. (about 53 inches) high; upper internode solid or hollow with thick walls.

Ear, slightly tapering towards the apex, 8-9 cm. long, almost square, 11-13 mm. across the sides; spikelets 19-20; D = 30-34; awns 18 cm. long, slightly divergent (Ear type 1, Fig. 143).

Empty glume, black, with a bluish-white surface, 9 mm. long; apical tooth 1-1·5 mm. long with broad base (4, 6, Fig. 138).

Grain, flinty, compressed, with high dorsal ridge, apex truncate, 8·2 mm. long, 3·65 mm. broad, 3·9 mm. thick.

A closely similar form to this from Bulgaria has ears 7-9 cm. long, almost square, 10-12 mm. across the sides, or compressed, 10 mm. across the face, and 13 mm. across the sides.

Ear beardless; glumes blue-black, glabrous; grain white.

T. durum, var. australe, mihi.

Huguenot or **Bald Medeah** (2, Fig. 146).—Received from Australia, where it is grown as a hay crop and for green feed in the coastal regions.

At Reading it is very early, coming into ear before the end of May.

Guthrie states that it originated from a single plant with two beardless heads in a crop of Medeah (var. *erythromelan*, p. 224). The selection was made in 1897 by J. Correll, Arthur River, Western Australia. G. L. Sutton notes that the original plant is supposed to have been a natural cross between Medeah and Purple straw (*T. vulgare*, var. *lutescens*).

Young shoots, erect.

Straw, stiff, erect, tall, 127 cm. (about 50 inches) high; upper internode solid and often wavy below the ear.

Ear, dense, 6·5-7 cm. long, tapering towards apex and bases, 9-10 mm. across the face, 15 mm. across the side; spikelets 22-24, 3-grained; D = 38.

Empty glume, 9-10 mm. long; apical tooth small, very short, ·5 mm. long; secondary tooth of empty glume distinct (14, Fig. 138).

Grain, flinty, with high dorsal ridge and bluntish apex; 7-8 mm. long, 3·5 mm. broad, 3·5 mm. thick.

Ear beardless; glumes red, glabrous; grain white.

T. durum, var. sub-australe, mihi.

Received from Australia in a sample of Bald Medeah (the previous variety), with which form it agrees in all respects except in the colour of the glumes.

CHAPTER XVI

POLISH WHEAT

Triticum polonicum, L. *Sp. Pl.* ed. ii. 127 (1762).
T. levissimum, Haller. *Stirp. ind. Helv.* 209, No. 1423 (1768).
T. glaucum, Moench. *Method.* 174 (1794).
Gigachilon polonicum, Seidl. Bercht. und Seidl, *Oek. tech. Flora Böhmens*, i. 425 (1836).
Deina polonica, Alef. *Landw. Fl.* 336 (1866).

POLISH wheat is the most modern of all the races or sub-races of wheat, there being no evidence of its existence before the first half of the seventeenth century.

Bauhin and Cherler (*Historia Plantarum universalis*, ii. 410, 1651) mention a " *Triticum speciosum grano longo* " obtained from the Botanic Garden at Stuttgart, which probably refers to Polish wheat, but the name *T. polonicum* is first met with in Hermann's list of plants grown in the Botanic Garden at Leyden during 1681–1686 (P. Hermann, *Hortus Academicus Lugduno-Batavus*, 609 (1687)).

The second reference to this wheat occurs in 1690 in Bobart's catalogue published as an appendix in Ray's *Synopsis Methodica Stirpium Britannicarum* (p. 236), where it is described as " *Triticum Poloniae. Triticum majus gluma foliacea*," with the note, " This I received first out of Worcestershire, where it is sown in the fields."

Plukenet in 1692 gives an excellent figure of an ear of the wheat in his *Phytographia* (Plate CCXXXI., Fig. 6) under the title " *Triticum Poloniam* H. Oxon ab ingeniosissimo Hortulano D. Harrison accepimus," and an ear similar to the one figured exists in Plukenet's Herbarium in the British Museum (*Herb. Sloane*, vol. xcviii. fol. 124).

Later in his *Almagestum*, 1696 (p. 378), Plukenet refers to the wheat as *Triticum Polonicum*, the name ultimately adopted by Linnaeus.

Morison (*Plantarum Historia Oxoniensis*, iii. 175 (1699)) describes it as " Triticum majus longiore grano glumis foliaceis incluso Poloniae dictum," and two specimens, var. *levissimum* and var. *villosum*, are found in the Morisonian Herbarium at Oxford.

From its first appearance it seems to have been grown in Botanic Gardens throughout Europe, and Haller in 1768 (*Stirp. ind. Helv.* ii. 209) says it was cultivated in Thuringia and in small amount in Switzerland.

Although the name "Polish" is associated with it in almost all the countries in which it is found, the origin of the name and the early connection of the wheat with Poland is obscure. Seringe (*Cér. eur.* 182) states that in 1816 and 1817 sixty vessels laden with this wheat arrived in France from Dantzig, and concludes that it was cultivated on a large scale in some of the northern countries. I have, however, discovered no satisfactory evidence of its growth in Poland before 1870 (Rostafinski, *Fl. Poloniae prodromus*, 26 (1873)).

Polish wheat is a delicate spring cereal, and requires a hot climate and fertile soil for satisfactory growth. In damp seasons at Reading it is almost completely sterile and in the best years there gives only poor yields of grain; the anthers frequently remain very small and shrivel, the filaments not elongating as in the other wheats. It is nowhere prolific and its cultivation is of little importance, since it possesses no qualities which are not found in greater degree in *T. durum*.

Small isolated areas are grown in several countries bordering the Mediterranean, more especially in Algeria, Spain, and Italy, where its grain is employed in the manufacture of macaroni. Schimper found it in Abyssinia with the native name "Fellasito," and I have had samples of it from Idaho, U.S.A., and from Argentina under the name "Trigo Chile de fideos." Flaksberger informs me that it is not found as a field crop in European Russia or Siberia, but is cultivated on a small scale in the Heyrabad district in Turkestan, where it is considered to be of Siberian origin.

To Polish wheat various names have been given, such as Siberian, Astrakhan, Mogadur, Surinam, and Chinese wheats. In outline the long narrow grain somewhat resembles a grain of rye, and with a specimen in the Herbarium at Kew is the record of 4 acres grown in Essex in 1858 and described by Dickson & Sons as "Giant Rye."

Körnicke states that a sample was sent to the Vienna Exhibition (? date) as Montana Rye from the United States, and that two samples obtained first and second prize as Rye at the Denver Exhibition, U.S.A., of 1882.

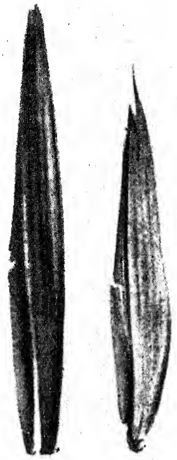
General Characters of *T. polonicum*, L.

The typical form of *T. polonicum* is strikingly different from all other wheats in possessing large ears with long, narrow, empty glumes of a glaucous hue, which extend beyond the rest of the spikelet.

It is one of the tallest wheats, its culms usually reaching a height of 140-160 cm. (about 55-60 inches). These generally have 5 internodes

above ground, averaging about 5·5 cm., 10·5 cm., 15 cm., 28 cm., and 54 cm., increasing from below upwards.

The upper internodes are generally solid, the lower ones more or less hollow. The tillering power is small, each plant rarely producing more than three or four straws.



1 2

FIG. 147.—Empty glumes of Polish wheat (*T. polonicum*) (nat. size).

1 2

FIG. 148.—Grains of Polish wheat (*T. polonicum*), front, back, and side views (nat. size).

The shoots of the young plants are of upright habit, their leaves bluish-green, with comparatively smooth surfaces like those of *T. durum*.

The culm leaves are almost glabrous, the upper ones 2 cm. or more broad with small auricles, which are generally free from hairs.

The ears have from 19 to 23 spikelets, three or four of the lower ones being abortive ; in some varieties they are lax, 14-16 cm. long, somewhat square in section, with a density of 15-18 ; in others they are 7-9 cm. long, oblong in section, and compact, the density being about 30.

The rachis is smooth and flattened, the margins fringed with hairs, which are longest near its nodes ; a frontal tuft of hairs 2-2·5 mm. long is also present

FIG. 149.—Grains of the spikelets of one side of an ear of Polish wheat (*T. polonicum*) (nat. size).

at the base of each spikelet. The spikelets are large, flattened, 3-4 cm. long, consisting of four or five flowers, of which two (or three) only produce grain, the others having anthers devoid of pollen and imperfectly developed ovaries.

The empty glumes are glabrous or pubescent, the hairs in the latter case usually very short and easily overlooked; they are as long as, or slightly longer than, the rest of the spikelet, 2-4 cm. long, lanceolate, and narrow, each measuring 4-5 mm. across its outer, wider, and convex half, and 2·5-3 mm. across the inner concave half, which is closely adpressed to the former.

They are fringed along the keel and possess 8-10 nerves, 5 or 6 on the outer broad half, 2 or 3 on the inner half, and a central nerve, which terminates on the short primary tooth ·5-3 mm. long; the secondary tooth is very short or altogether absent (Fig. 147).

The flowering glumes of the two lowest flowers are from 2 to 3 cm. long and 8-10 mm. broad, the upper ones being much shorter; they are boat-shaped, rounded on the back with 15-17 nerves, their membranous edges fringed with short hairs.

Those of the two lowest flowering glumes of the spikelet are bearded, each awn being 7-12 cm. long, frequently with a kink or bend in the basal portion; the awns of the upper flowering glumes are either very short, measuring not more than about 5 mm. long, or are entirely missing.

The paleae are only 1·2-1·5 cm. long, even in the lower flowers, whose flowering glumes are about twice this length; they are of the usual bicarinate lanceolate form, with a slightly divided tip, and possess 4 nerves.

The thin rachilla is convex, with fine hairs on one side and flat and more or less glabrous on the other.

The grains, which are the largest of all wheats, are yellowish-white, or pale red with flinty endosperm; they are long and narrow, measuring 11-12 mm. long and 4 mm. broad (Figs. 148, 149).

VARIETIES OF *T. polonicum*, L.

1. Glumes white, glabrous; awns short.
    - *a.* Ears cylindrical . . . . var. *incertum*, Körn.
    - *b.* Ears quadrate . . . . . . var. *submuticum*, Link.
    - *c.* Ears flattened, compact.
        - i. Short ears . . . . . . var. *compactum*, Link.
        - ii. Long ears . . . . . . var. *elongatum*, Körn.
2. Glumes white, glabrous; awns long.
    - *a.* Ear quadrate.
        - i. Grain white . . . . . var. *levissimum*, Körn.
        - ii. Grain red . . . . . . var. *chrysospermum*, Körn.

b. Ear flattened.
i. Awns white.
A. Ear broad at base.
(1) Spikelets narrow . . . . var. *abessinicum*, Körn.
(2) Spikelets wide . . . . var. *attenuatum*, Körn.
B. Ear broad at apex . . . . var. *intermedium*, Körn.
ii. Awns black . . . . var. *nigrobarbatum*, Körn.
3. Glumes white, pubescent ; awns short.
a. Ears flattened . . . . var. *vestitum*, Körn.
4. Glumes white, pubescent ; awns long.
a. Ear cylindrical.
i. Grain white . . . . . . var. *speltiforme*, Körn.
ii. Grain red . . . . . . var. *novissimum*, Körn.
b. Ears quadrate . . . . var. *villosum*, Körn.
c. Ears flattened.
i. Grain white . . . . . . var. *Martinari*, Körn.
ii. Grain red . . . . var. *Halleri*, Körn.
5. Glumes pale red, glabrous ; awns long.
a. Ears cylindrical . . . . var. *rufescens*, Körn.
6. Glumes pale red, pubescent ; awns long.
a. Ears cylindrical . . . . . . var. *rubrovelutinum*, Körn.
b. Ears quadrate.
i. Awns pale red . . . . var. *Seringei*, Körn.
ii. Awns black . . . . var. *Vilmorini*, Körn.
7. Glumes black, pubescent ; awns short.
a. Ears cylindrical . . . . var. *anomalum*, Körn.
8. Glumes pale violet, pubescent.
a. Ears quadrate . . . . var. *violaceum*, Körn.
9. Glumes blue-black, pubescent.
a. Ears quadrate . . . . var. *nigrescens*, Körn.

A large number of varieties of *T. polonicum* have been described or figured ; the majority of them are, however, not now in cultivation and do not appear to have been grown except in Botanic Gardens.

I have not been able to procure viable grain of any forms except those belonging to the varieties *levissimum*, *villosum*, and *Martinari*, and a single specimen of *aristinigrum* found among a sample of *villosum* ; the three first mentioned appear to be the only varieties found at present in field culture.

Seringe divided *T. polonicum* into four groups, viz. :

1. *T. polonicum quadratum*, long, lax, square-eared forms.

2. *T. polonicum oblongum*, forms with long, lax, somewhat cylindrical ears with affinities near to *T. durum*.

3. *T. polonicum compactum*, forms with ovate dense ears.

4. *T. polonicum deformatum*, forms with deformed or branched ears with short, poorly-developed grains.

In each group Seringe mentions several "variations," but these are now entirely lost. Early specimens I have seen in various herbaria, and several of the figures given by Seringe belonging to Groups 1 and 2 have narrow regular ears, and empty glumes intermediate in length between the typical long-glumed *T. polonicum* and *T. durum*; I have little doubt that these are of hybrid origin.

It is probable that *T. polonicum* originated as a mutation of *T. durum*, or as a race resulting from the hybridisation of the latter with some other wheat, and may have been specially unstable and subject to further mutation or natural hybridisation in Seringe's day.

Branching of the ear is uncommon in *T. polonicum*, but occurs occasionally; Seringe's *deformatum* shows this character, and Bayle-Barelle (*Mon. agr. Cer.* 38, t. 2, Fig. 8) figures a proliferous ear under the title "*T. polonicum hybridum horti ticinensis*"; Metzger also describes and figures a compound ear of this species.

Glumes white, glabrous; ear cylindrical; awns short.

T. polonicum, var. **incertum**, Körn. *Handb. d. Getr.* i. 100 (1885).

T. polonicum oblongum, var. J., Ser. *Cér. eur.* 147 (185) (1841).

The ears are long and cylindrical, the spikelets wide apart and adpressed to the rachis.

Glumes white, glabrous; ear quadrate; awns short.

T. polonicum, var. **submuticum**, Link. *Hort. Berol.* i. 28 (1827).

T. polonicum, D., Metzger. *Eur. Cer.* 25, t. 5, B., C. (1824).

T. polonicum aristis brevibus, Krause. *Getr.* Heft iv. 5, t. 2, B. (1836).

Of this variety Metzger gives the following characters:

Straw, tall, 110-120 cm. (about 44-48 inches) high, solid, striated, yellowish-white; leaves 15-17 cm. long, 1·5 cm. wide.

Ears, 12-15 cm. (4·75-6 inches) long, lax, 4-sided, compressed, tapering towards the apex; spikelets 20-24, 25-30 mm. long, 18-20 mm. wide, 2- to 3-grained, with short awns 1·5-5 cm. long.

Empty glume, 2·5 cm. long, with six prominent nerves and two teeth, one longer than the other; flowering glumes as long as the empty glume with a short awn and many nerves; palea half as long as the flowering glume.

Grain, long, pointed, smooth, pale greyish-white, flinty.

Glumes white, glabrous; ear flattened, short, compact; awns short.

T. polonicum, var. **compactum**, Link. *Hort. Berol.* i. 28 (1827).

T. polonicum, E., Metzger. *Eur. Cer.* 25, t. V. Fig. C. (1824).

T. polonicum compactum, Krause. *Getr.* Heft iv. 7, Taf. 2, C., D. (1836).

T. polonicum compactum, var. M., Ser. *Cér. eur.* 148 (186) (1841).

Metzger states that this variety is grown in Granada, and notes that in wet years it produces very little grain.

The following description is from Metzger:

Straw, tall, 120 cm. (about 48 inches) high, erect, striated, and solid; leaves 15-20 cm. long, 1·5 cm. wide.

Ear, usually very dense, but sometimes laxer, 7·5-10 cm. long, quadrate, generally tapered towards the apex, but occasionally broader upwards; spikelets 14-16, 2·5 cm. long, 1·25 cm. wide, 2- to 3-grained; awns 1 or 2, 1·5-5 cm. long.

Empty glume, 2·5 cm. long, glabrous, with 5 nerves on the broadest half; apical teeth two, the outer larger than the inner one.

Grain, 1·25 cm. long, greyish-white, pointed, flinty, the surface wrinkled.

Glumes white, glabrous; ear long, flattened, compact; awns short.

T. polonicum, var. **elongatum,** Körn. *Handb. d. Getr.* i. 102 (1885).

T. polonicum compactum, var. L., Ser. *Cér. eur.* 148 (186) (1841).

A variety with long compact ears mentioned by Seringe; the ears are often curved.

Glumes glabrous, white; grain white; ear quadrate, lax; awns long.

T. polonicum, var. **levissimum,** Körn. *Handb. d. Getr.* i. 100 (1885).

T. levissimum, Haller. *Hist. Stirp. indig. Helvetiae*, ii. 209, No. 1423 (1768).

Deina polonica alba, Alef. *Landw. Fl.* p. 336 (1866).

This and its pubescent counterpart var. *villosum* are two of the most widely distributed varieties of Polish wheat.

Young plants, erect; young leaves glabrous.

Straw, tall, 110-120 cm. (about 44-48 inches) high, erect, solid, striated; leaves 15-20 cm. long, 1·5-2 cm. wide.

Ear, 12·5-17·5 cm. (5-7 inches) long, very lax, slightly tapered at the apex; spikelets 14-18, 2- to 3-seeded, 2·5-3·5 cm. long.

Empty glume, 25-30 mm. long, 3 mm. wide, with 5-6 prominent nerves on the outer half; keel ciliated, the hairs very fine; apex with two teeth.

Flowering glume, as long as the empty glume, with fine brittle awns half as long as the ear.

Grain, 1·25 cm. long or longer, somewhat pointed, flinty, the surface wrinkled.

Glumes glabrous, white; grain red; ear quadrate, lax; awns long.

T. polonicum, var. **chrysospermum,** Körn. *Handb. d. Getr.* i. 101 (1885).

Körnicke's type has white smooth ears 11·5 cm. long; the empty glumes 2·5-3 cm. long; awns of moderate length, and red grain 9 mm. long. He states that at first the glumes were slightly pubescent, but in later seasons became glabrous.

Glumes white, glabrous; ear dense, flattened, broad at base; spikelets narrow; awns long, white.

T. polonicum, var. **abessinicum,** Körn. *Handb. d. Getr.* i. 103 (1885).

Collected by Schimper in Abyssinia ; the native name is " Fellasito."

Körnicke states that the ears are 8 cm. long, slightly narrowed towards the apex, very dense, strongly compressed, narrow across the face, but 2 cm. wide across the 2-rowed side ; awns 15 cm. long. The glabrous pale yellow, empty glumes are 2·5 cm. long, with a terminal awn-like point which in some instances reaches a length of 18 mm.

Grain, white, somewhat short and broad, 7 mm. long (unripe specimens).

Steudel's *T. abyssinicum* (*Synops. Gram.* 342, No. 19) appears to be a similar dense-eared form of *T. polonicum* grown in Abyssinia.

Glumes white, glabrous ; ear dense, flattened, broad at base ; spikelets wide ; awns long, white.

T. polonicum, var. **attenuatum**, Körn. *Handb. d. Getr.* i. 104 (1885).

T. polonicum, var. *longiaristatum*, b., *crassispicatum*, Körn. *Syst. Uebers.* 15 (1873).

Körnicke's type, which was obtained from a Botanic Garden, possesses ears 8 cm. long or longer and white grain.

Glumes white, glabrous ; ear broadest at apex ; awns long, white.

T. polonicum, var. **intermedium**, Körn. *Handb. d. Getr.* i. 104 (1885).

T. polonicum compactum, var. K., Ser. *Cér. eur.* 148 (186), t. 8 (16), Fig 4 (1841).

A " club-eared " form of *T. polonicum* mentioned and figured by Seringe. The ears are lax at the base and dense at the blunt apex.

Glumes white, glabrous ; ear flattened ; awns long, black.

T. polonicum, var. **nigrobarbatum**, Körn. *Handb. d. Getr.* i. 109 (1885).

T. polonicum nigrobarbatum, Desv. *From.* 149 (1833).

T. polonicum compactum, var. O., Ser. *Cér. eur.* 148 (186) (1841).

A compact-eared variety mentioned by Desvaux and Seringe.

Glumes white, pubescent ; ear dense, flattened ; awns short.

T. polonicum, var. **vestitum**, Körn. *Handb. d. Getr.* i. 103 (1885).

T. polonicum compactum, var. N., Ser. *Cér. eur.* 148 (186) (1841).

A dense compact-eared variety mentioned by Seringe; similar to var. *compactum*, Link, but with pubescent glumes.

Glumes white, pubescent ; ear lax, cylindrical ; grain white or pale yellow.

T. polonicum, var. **speltiforme**, Körn. *Archiv f. Biontologie*, ii. 403 (1908).

A form sent to Körnicke by H. de Vilmorin and apparently of hybrid origin (*T. polonicum levissimum* (or *villosum*) × *T. turgidum*, var. *lusitanicum*, Pétianelle blanche). The ears are very narrow, lax, with awns of variable length (0-18 cm.) ; empty glumes as long as the spikelets, the grain comparatively short like that of *T. durum*.

Glumes white, pubescent ; ear cylindrical ; awns long ; grain red.

T. polonicum, var. **novissimum**, Körn. *Archiv. f. Biontologie*, ii. 404 (1908).

A narrow-eared form apparently of hybrid origin (*T. polonicum* × *T. durum* ?).

Glumes white, pubescent ; ear quadrate ; awns long.

T. polonicum, var. **villosum**, Körn. *Handb. d. Getr.* i. 101 (1885).
T. polonicum villosum, Desv. *From.* 146 (1833).
T. polonicum, Lagasca. *Gen. et sp. pl.* 6 (1814).
T. polonicum, C., Metzger. *Eur. Cer.* 25 (1824).
T. polonicum quadratum, var. B., Ser. *Cér. eur.* 146 (184) (1841).
T. polonicum velutinum, Krause. *Getr.* Heft iv. 5, t. 2, A. (1836).
Deina polonica velutinum, Alef. *Landw. Fl.* 336 (1866).

This and its glabrous counterpart var. *levissimum* are two of the most widely known varieties of *T. polonicum*.

Young shoots, erect or semi-erect.

Straw, tall, 125-130 cm. (about 50-52 inches) high; upper internode almost solid.

Ear, lax, 15-17 cm. long, 10 mm. across the face, 12-15 mm. across the 2-rowed side; spikelets 15-22, 30-35 mm. long, 3-4 abortive at the base of the ear, the rest 3- to 4-flowered, the lower 2 or 3 flowers of each fertile; D = 15-18.

Edges of the rachis fringed with hairs 1-2 mm. long.

Empty glume, thin, narrow, lanceolate, those of the lower flowers 30-35 mm. long, keeled, outer half with five prominent longitudinal ciliate nerves, the hairs very fine ; apex with short acute primary tooth and rudimentary secondary tooth close to the primary tooth (1, Fig. 147).

Flowering glumes of the two lower flowers with awns 9-11 cm. long, those of the upper flowers with a short point about 1 mm. long, palea of the lower flowers about half the length of the flowering glume.

Grain, flinty, long and narrow, pointed at the base, blunt at the apex; 10-12 mm. long, 3-3·1 mm. broad, 2·9 mm. thick (1, Fig. 148).

Glumes white, pubescent ; ear dense ; awns long ; grain white.

T. polonicum, var. **Martinari**, Körn. *Handb. d. Getr.* i. 104 (1885).

Körnicke's type has dense ears, 8 cm. long, attenuated towards the apex the empty glumes with awn-like points 6 mm. long. It originated from a sample exhibited as "Grano S. Martinaro" at the Italian Exhibition in Paris, 1878.

Trigo Chile de fideos (1, Fig. 150).—A form of var. *Martinari* received from Argentina and Spain.

Young shoots, semi-erect.

Straw, slender, of medium height, 110-115 mm. (42-44 inches) high; upper node solid.

Ear, dense, 8-9 cm. long, outline more or less ovate, tapering towards the apex; compressed, 10-15 mm. across the face, about 20 mm. across the 2-rowed

1

2

FIG. 150.—POLISH WHEAT (*T. polonicum*, L.).

1. var. *Martinari*.
(Trigo Chile de fideos.)

2. var. *villosum*.

side; awns of the two lowest flowering glumes of each spikelet 10-13 cm. long, those of the third flower about 1 cm. long; spikelets 21-23, each 20-25 mm. long, 10-14 mm. broad; D = 28-30.

Empty glume, keeled to the base, 25-27 mm. long, outer half narrow, lanceolate with 5 or 6 nerves; primary apical tooth 1-3 mm. long or longer; secondary tooth about 1 mm. long (2, Fig. 147).

Grain, flinty, pointed at the base, apex blunt; 9·5-11 mm. long, 3·3 mm. broad, 3·2 mm. thick (2, Fig. 148).

Glumes white, pubescent; ear dense; awns long; grain red.

T. polonicum, var. **Halleri**, Körn. *Handb. d. Getr.* i. 104 (1885).

A variety with dense ears 5-7 cm. long, 2 cm. or more wide, the shorter ears more or less oval in outline. Körnicke's type was obtained from a Botanic Garden.

Körnicke describes a var. *pseudohalleri* with a somewhat lax, square, glabrous ear, remarking that it "differs from var. *Halleri* in its red grain"! (*Archiv f. Biontologie*, ii. 404 (1908).

Glumes pale red, glabrous; awns long; ears cylindrical.

T. polonicum, var. **rufescens**, Körn. *Handb. d. Getr.* i. 100 (1885).

Körnicke's type has narrow pale red ears, 9-12 cm. long, moderately dense with long awns and reddish grain.

T. polonicum oblongum, var. G., Ser. (*Cér. eur.* 147 (185) (1841)), is similar, but with very lax ears.

Glumes pale red, pubescent; awns long, red; ear cylindrical, lax.

T. polonicum, var. **rubrovelutinum**, Körn. *Handb. d. Getr.* i. 100 (1885).

T. polonicum oblongum, var. H., Ser. *Cér. eur.* 147 (185) (1841).

A variety with very lax, pale red, pubescent ears mentioned by Seringe.

Glumes red, pubescent; awns long, pale red; ear quadrate, lax.

T. polonicum Seringei, Körn. *Handb. d. Getr.* i. 101 (1885).

T. polonicum quadratum, var. C., Ser. *Cér. eur.* 146 (184) (1841).

A variety mentioned by Seringe.

Glumes pale red, pubescent; awns long, black; ear quadrate, lax.

T. polonicum, var. **Vilmorini**, Körn. *Handb. d. Getr.* i. 101 (1885).

T. polonicum quadratum, var. D., Ser. *Cér. eur.* 146 (184) (1841).

A variety mentioned by Seringe (= *T. polonicum*, Vilmorin, No. 74, 1836).

Glumes black, pubescent; ear cylindrical; awns short.

T. polonicum, var. **anomalum**, Körn. *Handb. d. Getr.* i. 100 (1885).

T. polonicum oblongum, var. I., Ser. *Cér. eur.* 147 (185), Pl. IX. (Fig. 2) (1841).

A variety with lax, slightly-compressed ears, which are almost beardless, possessing only a few short awns at the apex.

Glumes pale violet, pubescent ; ear quadrate, lax.

T. polonicum, var. **violaceum**, Körn. *Handb. d. Getr.* i. 101 (1885).
T. polonicum quadratum, var. E., Ser. *Cér. eur.* 146 (184) (1841).
A variety mentioned by Seringe, cultivated in the Botanic Garden at Lyon, 1836.

Glumes bluish-black, pubescent ; ear quadrate, lax.

T. polonicum, var. **nigrescens**, Körn. *Handb. d. Getr.* i. 101 (1885).
T. polonicum quadratum, var. F., Ser. *Cér. eur.* 146 (184) (1841).
A variety mentioned by Seringe with regularly arranged spikelets and blue-black glumes and awns (= *T. polonicum*, Vilmorin, No. 5 (1836)).

CHAPTER XVII

RIVET OR CONE WHEAT

T. turgidum, L. *Sp. Pl.* 86 (1753).
T. vulgare turgidum, Alef. *Landw. Fl.* 325 (1866).
T. sativum turgidum, Hackel. *Nat. Pfl.* ii. 2, 85 (1887).

THE existence of Rivet wheat in prehistoric times is very doubtful. Heer obtained from the pile-dwelling deposits of Robenhausen (Switzerland) grains and a portion of a dense ear which he attributed to this race, and large grains described as those of *T. turgidum* have been recorded also from deposits of Neolithic and Bronze Ages in Italy (Castione, Parma); owing, however, to the difficulty of distinguishing grains of some of the forms of *T. turgidum*, *T. vulgare*, and *T. durum*, even in recent material these conclusions must be considered problematical.

On similar grounds the statement of A. de Candolle, that he recognised grains of this wheat among seeds taken from the sarcophagi of ancient Egyptian tombs, should be accepted with reserve.

There are no descriptions of wheats among ancient Greek or Latin authors which conclusively point to this race; it is possible, however, that the " *triticum ramosum* " of Pliny refers to one or other of the varieties of *T. turgidum* with branched ears, of which the simple-eared forms would, no doubt, exist.

The clear separation of *T. turgidum* from *T. vulgare* and *T. durum* does not appear to have been recorded until the first half of the sixteenth century, when Fuchs (1542) and other " herbalists " accurately describe and figure it under the name " Welsch " wheat, *i.e.* wheat from the Welschland (France and Italy).

Dodoens also speaks of it as Roman wheat or *Triticum romanorum*, and distinguishes it from the allied *Triticum typhinum* (*T. durum*), " Typhew " wheat, which he obtained from the Canary Isles and Spain.

Several varieties of this race of wheat were cultivated somewhat widely in England in the sixteenth, seventeenth, and eighteenth centuries, at which period they were designated Rivet, Cone, or Pollard wheats. During the latter half of the nineteenth century they were less commonly

grown ; at the present time only one or two forms of Rivet wheat are found on farms in this country, and these only on comparatively small areas, chiefly in the southern counties. Their high yield will, however, always attract attention, and there is some likelihood of their being increasingly grown in the future on this account.

In Germany this race is termed " English Wheat " ; under the name Blé Poulard it is met with in France, but the home of Rivet wheat is in the countries bordering the Mediterranean. It is especially frequent in Spain and Portugal and Italy, but several forms are grown in lesser degree in Bulgaria, Greece, and Turkey. It is also cultivated extensively in the Provinces of Tiflis and Baku in Transcaucasia, and in smaller amount in Turkestan and Siberia ; Howard records its occurrence in Baluchistan, but I have not seen specimens.

Small areas are occasionally devoted to this wheat in Australia, Canada, the United States, South Africa, Chili, and Algeria.

I have no specimens nor records of its cultivation from India, China, Japan, or Abyssinia.

Although some of the red and blue-black velvet-chaffed varieties can be cultivated as winter wheats in the south of England, France, and Germany without much risk in ordinary seasons, the majority of the Rivet wheats are delicate and easily damaged, or destroyed altogether by hard frosts or continued rain.

They are practically immune to rust fungi. I have never seen a field crop nor yet a small plot or row of any variety of *T. turgidum* attacked on ordinary cultivated soils in this country, but in 1908 I observed an extensive invasion of yellow rust (*Puccinia glumarum*) on Blue Cone wheat (*T. turgidum*, var. *iodurum*) sown late in spring on a small plot of highly manured ground, which had been trenched 3 feet deep.

Their tall straw is strong, the crop rarely lodges, and the stiff awned ears are not readily damaged by sparrows and other birds.

The varieties grown in England have very narrow blue-green leaves, which lie close to the ground during winter ; in February, when ordinary varieties of *T. vulgare* usually exhibit a vigorous growth of leafy shoots 2 or 3 inches high, Rivet wheats have a disappointing appearance, and the farmer who is not familiar with their habit is inclined to plough them up at this season. They should, however, be left, for their progress later invariably compensates for the apparent lack of vigour in the early stages of their development.

The productive power of most varieties of *T. turgidum* is greater than that of any other race of wheat when the soil is suitable and the climate allows of a long growing period for the crop.

Their high grain-yielding capacity is correlated with the long vegetative period of the plants, the usual possession of six or seven green leaves on

each straw, as well as with the great length of their stems and leaves, and consequent abundance of green assimilating tissue. Moreover, the number of spikelets possessed by each ear is usually greater among the varieties of *T. turgidum* than among the varieties of *T. vulgare*.

To ensure the greatest success with these wheats in England they should be sown not later than the middle of October on warm, well-drained soils; when sown in spring they ripen very late, and the grain at harvest is often poorly filled.

A few varieties possess flinty grains, but the majority of Rivet wheats have a soft, opaque, starchy endosperm, from which is obtained "weak" flour, suited to the requirements of the biscuit-maker, but of less value to the baker on account of the poor physical quality and reduced amount of its gluten. The dough is somewhat greyish and "short"; loaves of bread made from Rivet flour are more or less dense and non-porous in texture, and of small volume when compared with loaves made from the same weight of dough prepared from the "strong" flour of certain varieties of *T. vulgare*.

The bran is thick and abundant.

Rivet wheats are chiefly utilised by the miller for mixing with the strong Canadian and Russian wheats.

General Characters of *T. turgidum*, L.

T. turgidum is the tallest of the wheats; its straw, which is somewhat slender but strong, with a dull striate surface, averages about 150 cm. (69 inches), the length in different varieties measuring from 120 to 180 cm. (48 to 72 inches) or more; the upper internode is curved and in many cases solid or filled with pith; even in those varieties with all the internodes hollow the wall of the straw is often thick and pithy and the central cavity comparatively small. I have found none with walls as thin as those of *T. vulgare*.

Well-developed culms of many kinds possess six or seven internodes above ground; the average lengths of the successive internodes from below upwards were found in a few common varieties to measure 5, 10·5, 14·5, 19, 29, and 60 cm. respectively.

In some varieties the young shoots have the prostrate "winter" habit; others have the semi-erect or erect "spring" habit.

The leaves of the young plants are short, narrow, and usually dark bluish-green, those of the culm long and broad.

In almost all varieties both sides are invested with soft white hairs from 120 to 250 μ long, as in *T. dicoccum*, the leaves to the touch resembling velvet and appearing clothed with a silvery covering when viewed along the surface (Fig. 151). Some forms of var. *dinurum* have young leaves

which appear almost smooth, the hairs upon them measuring not more than 32-64 μ long, the older leaves of such varieties being somewhat scabrid.

The auricles are usually fringed with a few long hairs.

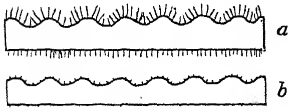


FIG. 151.—Diagrammatic transverse sections of young leaves of (*a*) *T. turgidum* and *T. pyramidale*, (*b*) *T. turgidum* (var. *dinurum*).

The ears are large, pendulous, heavy, and nearly always bearded, the sides usually parallel, though a few taper a little towards the tip. The ears are square or oblong in section, the form in this respect depending upon the laxness or density of the ear and the number and size of the grains which develop in each spikelet. Ears with closely packed spikelets containing four or five grains are almost square; those in which the spikelets are densely packed and contain only two or three grains are oblong in section and broadest across the side. A few forms with lax ears and well-filled spikelets are broad across the face and narrow across the side like most of the varieties of *T. vulgare*.

The ears of different forms are from 7 cm. to 11·5 cm. in length, their " density " varying from 21 to over 40, the individual rachis internodes measuring from 2·5 mm. to 4·66 mm.

The number of spikelets possessed by an average ear varies from 19 to 33.

The rachis is tough, except in a few forms, which are brittle like those of *T. dicoccum*; it is smooth, but copiously fringed along its edges with white hairs, and at the apex of each of its internodes at the base of the spikelets is a tuft of similar hairs from 1 to 2 mm. in length.

The spikelets are from 8 to 15 mm. broad, 10 to 13 mm. long, and about 4 mm. thick. They are usually 5- to 7-flowered, and in some varieties many of them produce three to five well-developed grains.

The empty glumes are white, yellow, red, or dark bluish, the black or dark brown pigment in the latter case being modified by a glaucous covering.

As in *T. durum* and other wheats, the power of forming black pigment in the glumes and awns appears to be absent from some varieties; in those forms which possess it the colour is not always produced, its appearance being dependent upon climatic conditions. In damp cold seasons, and in very dry seasons, when the plant is prevented from developing its ears fully, the colour is more or less completely kept in abeyance, but in bright warm seasons it appears again, such variation occurring in plants of " pedigree " lines.

In some forms the glumes are glabrous, in others they are pubescent. They are comparatively short; those of the lateral spikelets are 8-11 mm. long, more inflated than those of *T. durum*, unsymmetrical, and 5- to 7-

nerved, the portion from the midrib to the outer edge being 4-5 mm. across, the inner membranous part being half as wide. The strong apical tooth in some varieties is acutely pointed, 1-1·5 mm. long, and curved inwards, in others short and blunt. A well-marked keel runs from the base to the

1 2 3 4 5 6 7 8 9

FIG. 152.—Empty glumes of Rivet wheat (*T. turgidum*) (× 2).

tip, and a more or less prominent lateral nerve is present on the outer broad half of the glume, running from the base to a point close to the apical tooth, where in some forms it terminates in a short secondary tooth (Fig. 152).

FIG. 153.—Grains of Rivet wheat (*T. turgidum*), front, back, and side views (nat. size).

The empty glumes of the terminal spikelet are ovate and more or less symmetrical (Fig. 78).

The flowering glumes are thin, fragile, and pale ; even in the black-eared varieties the dark tint is not developed in the part covered by the empty glume. They are oval, inflated, and boat-shaped, without a

keel, but possessing 9-15 fine nerves, which converge at the tip into the terminal awn.

FIG. 154.—Grains of the spikelets of one side of an ear of Rivet wheat (*T. turgidum*) (Blue Cone) (nat. size).

The awns are stout, yellowish-white, red, or black, from 8 to 16 cm. in length, triangular in section, the angles from the base to the apex being set with scabrid forward-pointing projections.

In a few varieties the awns diverge slightly outwards; usually, however, they are parallel to each other and to the long axis of the ear. Several kinds shed their awns when the grain is ripe.

As a rule only the two lower flowering glumes of the spikelet bear long awns; those of the third and higher flowers are much shorter or altogether missing.

The palea is membranous and of the normal bi-nerved form.

The typical grain is white, yellow, or red, large, broad, and plump, though sometimes flattened on one side by pressure of the empty glume, blunt or truncate at the "brush" end, with a high dorsal arch or hump behind the embryo. The furrow is shallow and the ventral flanks rounded in well-grown grains (Fig. 153).

In a few forms the caryopses are narrower towards the apex, though rarely so much as in *T. durum* and *T. dicoccum*. In a small number the dorsal arch is reduced, the grain then approximating to that of *T. vulgare*.

In some seasons, and especially when the crop is sown late, the grains at harvest exhibit a somewhat rough surface, and are poorly filled; this result is most evident among varieties possessing the largest grains.

The embryo is comparatively small and the endosperm usually opaque and starchy, although in a few forms it is flinty.

Measurements of grains taken from the middle of the ear of thirty-eight varieties gave the following results:

	Length.	Breadth.	Thickness.
	mm.	mm.	mm.
Average	7·45	3·88	3·70
Limits	6·7-8·37	3·26-4·43	3·23-4·1
Ratio	100	52·0	49·6

The long growing period, number of culm leaves, velvety leaf-surface, the height, surface, and pithy interior of its straw, the density of the ear, as well as the frequent occurrence of compound ears, indicate a close relationship of *T. turgidum* with the tall European forms of *T. dicoccum*.

A few forms suggest affinity with *T. durum*, while others appear to be allied to *T. vulgare*; these are probably hybrids.

VARIETIES OF *T. turgidum*, L.

I. *Ears bearded*—

1. Glumes white, glabrous; awns white.
   - i. Ear simple, grain white . . . var. *lusitanicum*, Körn.
   - ii. Ear simple, grain red . . . . var. *gentile*, Körn.
   - iii. Ear branched, grain red . . . var. *columbinum*, Körn.
2. Glumes white, glabrous; awns black.
   - i. Ear simple, grain white . . . var. *melanatherum*, Körn.
   - ii. Ear simple, grain red . . . var. *nigrobarbatum*, Körn.
   - iii. Ear branched, grain red . . . var. *pavoninum*, Körn.
3. Glumes white, pubescent; awns white.
   - i. Ear simple, grain white . . . var. *megalopolitanum*, Körn.
   - ii. Ear simple, grain red . . . . var. *buccale*, Körn.
   - iii. Ear branched, grain red . . . var. *centigranum*, Körn.
   - iv. Ear branched, grain red-violet . . var. *modigenitum*. Körn.
4. Glumes white, pubescent; awns black.
   - i. Ear simple, grain white . . . . var. *Salomonis*, Körn.
5. Glumes red, glabrous; awns red.
   - i. Ear simple, grain white . . . var. *Dreischianum*, Körn.
   - ii. Ear branched, grain white . . var. *pseudocervinum*, Körn.
   - iii. Ear simple, grain red . . . . var. *speciosum*, Körn.
   - iv. Ear branched, grain red . . . . var. *cervinum*, Körn.
6. Glumes red, glabrous; awns black.
   - i. Ear simple, grain white . . . var. *speciosissimum*, Körn.
   - ii. Ear branched, grain white . . var. *Plinianum*, Körn.
   - iii. Ear simple, grain red . . . . var. *Mertensii*, Körn.
7. Glumes red, pubescent; awns red.
   - i. Ear simple, grain white . . . var. *pseudomirabile*, mihi.
   - ii. Ear branched, grain white . . . var. *mirabile*, Körn.
   - iii. Ear simple, grain red . . . . var. *dinurum*, Körn.
   - iv. Ear branched, grain red . . . var. *Linnaeanum*, Körn.

8. Glumes red, pubescent; awns black.
    i. Ear simple, grain red . . . . var. *rubroatrum*, Körn.
9. Glumes blue-black, glabrous; awns black.
    i. Ear simple, grain white . . . . var. *Herrerae*, Körn.
10. Glumes blue-black, pubescent.
    i. Ear simple, grain red . . . . var. *iodurum*, Körn.
    ii. Ear branched, grain red . . . . var. *coeleste*, Körn.

II. *Ears beardless*—
1. Glumes blue-black, pubescent.
    i. Ear simple, grain red . . . . var. *subiodurum*, Körn.

Ear bearded, simple; glumes white, glabrous; awns white; grain white.

T. turgidum, var. **lusitanicum**, Körn. *Handb. d. Getr.* i. 59 (1885).
A widely distributed variety cultivated in France, Spain, and Greece, and according to Körnicke in Portugal, Italy, and Chili; Flaksberger mentions the occurrence of this variety in small amounts in Russia, Turkestan, and Siberia.

1. **Trigo Santa Salamanca.**—A spring form received from Spain.

Young shoots, semi-erect; young leaves pubescent.

Straw, very tall, 140 cm. (about 55 inches) high; upper internode solid.

Ear, lax, 10-11 cm. long, square, 10-11 mm. across the sides, or somewhat compressed, 9-11 mm. across the face, and 11-14 mm. across the side; edges of the rachis with long hairs; spikelets 23-26, 2- to 3-grained; D=25-27; awns rough, 16-20 cm. long (Ear type 2, Fig. 156).

Empty glume, flattish, 8 mm. long with acute apical tooth (2, Fig. 152).

Grain, very large, flinty, narrowed at the truncate apex, dorsal hump prominent; 8-9 mm. long, 4 mm. broad, 3·75 mm. thick.

2. A winter form received from Greece and Italy.

Young shoots, prostrate or semi-erect; young leaves pubescent.

Straw, hollow, with thick walls.

Ear, 7-10 cm. long, square, 10-12 mm. across the side, or somewhat compressed, 9-10 mm. across the face, and 10-12 mm. across the side; spikelets 22-24, 3-grained; D=30-33; awns 9 cm. long (Ear type 2, Fig. 157).

Empty glume, 8 mm. long; apex narrowed, sometimes with a black line along the margin; apical tooth short, acute (1, Fig. 152).

Grain, large, mealy; apex truncate; dorsal hump prominent; 8·2-8·5 mm. long, 4-4·4 mm. broad.

3. **Pétianelle blanche** or **Blé Hybride Galland.**—A winter or early spring form received from France.

Vilmorin states this form is cultivated in Central and Southern Italy, from which country it was introduced into France; it is a strong-growing form adapted to alluvial and the stiffer loamy soils in a warm climate.

Young shoots, semi-erect; young leaves pubescent.

Straw, very tall, coarse, striate, 152 cm. (about 60 inches) high; upper internode hollow with thick walls.

FIG. 155.—RIVET WHEAT (*T. turgidum*, L.).
var. *gentile*.
(Pisana blanca.)

Ear, 9-11 cm. long, much compressed, 9-10 mm. across the face, 14-15 mm. across the side; spikelets 27-32, 2- to 3-grained; D=33-36; awns 11-12 cm. long, deciduous (Ear type 2, Fig. 156).

Empty glume, 6·5-8 mm. long, apical tooth short, blunt (6, Fig. 152).

Grain, more or less flinty, large, often dark brown at the radicle end, dorsal hump prominent; 8·5-8·9 mm. long, 4 mm. broad, 3·7 mm. thick.

4. A smaller form resembling *Pétianelle blanche*, received from Greece.

Ears, 7-8 cm. long, compressed, 9-10 mm. across the face, 12-14 mm. across the side. *Empty glume*, with more acute tooth, but grain as in *Pétianelle blanche.*

Ear bearded, simple; glumes white, glabrous; awns white; grain red.

T. turgidum, var. **gentile**, Körn. *Handb. d. Getr.* i. 59 (1885).

A widely cultivated variety chiefly grown in Spain, Italy, Turkey, and to a small extent in France and the Midlands and eastern parts of England.

1. **Pisana blanca.**—A distinct winter form received from Spain; the flat-faced and narrow-sided ear suggests affinity with *T. vulgare.*

Young shoots, prostrate; young leaves pubescent.

Straw, very tall, 152 cm. (about 60 inches) high; upper internode solid.

Ear, lax, 9-11 cm. long, 13-15 mm. across the face, 9-10 mm. across the side; spikelets 19-24, widely separated and somewhat irregularly arranged on the rachis, 3- to 4-grained; D=20-23; awns 10 cm. long, slender, divergent, and deciduous (Ear type, Fig. 155).

Empty glume, 7-8 mm. long; apical tooth blunt (6, Fig. 152).

Grain, mealy, somewhat narrowed at the apex, dorsal hump prominent; 7·2-7·8 mm. long, 3·3-3·8 mm. broad, 3·3 mm. thick.

2. **Poulard Blanc Taganrog.**—A winter or spring form received from France and Germany; the name suggests that this form is of Russian origin, but Flaksberger states that var. *gentile* is not found in Russia. Vilmorin states that it is grown in Central France and gives a good yield if sown not later than the early part of November; it is adapted to calcareous soils and those of moderate quality.

Young shoots, semi-erect; young leaves pubescent.

Straw, tall, 140 cm. (about 56 inches) high; upper internode solid or hollow with thick walls.

Ear, 9-11 cm. long, apex tapered, square, 10-12 mm. across the face and side; spikelets 28-32, 3-grained; D=28-32; awns slender, 10-11 cm. long, deciduous (Ear type 1, Fig. 157).

Empty glume, short (7 mm. long), apex narrow, apical tooth acute, 1-1·5 mm. long (1, Fig. 152).

Grain, visible between the small short glumes, mealy, plump; apex narrowed, truncate; dorsal hump prominent; 7-7·5 mm. long, 3·5-3·8 mm. broad, 3·5-3·8 mm. thick.

3. **Biancone.**—Spring form received from Italy.

Young shoots, erect; young leaves pubescent; hairs short.

Straw, of medium height, 125 cm. (about 50 inches) high; upper internode hollow.

Ear, 8·5-10 cm. long, more or less compressed, 9-10 mm. across the face, 12-13 mm. across the side; spikelets 25-28, 3-grained; D=30; awns 12-13 cm. long, deciduous (Ear type 1, Fig. 157).

Empty glume, 7-8 mm. long, apex narrow, apical tooth short and blunt (3, 6, Fig. 152).

Grain, mealy, large, pale reddish-white, dorsal hump prominent; 8-8·5 mm. long, 4-4·3 mm. broad, 4 mm. thick.

4. **Ak Bashak** (=White Ear).—A winter form received from European Turkey.

Young shoots, prostrate; young leaves pubescent.

Straw, of medium height, 125 cm. (about 50 inches) high; upper internode solid, or hollow with very thick walls.

Ear, 9-10 cm. long, compressed, 10 mm. across the face, 14-15 mm. across the side; spikelets 22-25, 2- to 3-grained; D=25-29; awns 12-14 cm. long (Ear type 1, Fig. 157).

Empty glume, 9 mm. long, apical tooth short and blunt (6, 7, Fig. 152).

Grain, semi-flinty, large, reddish-white; apex somewhat narrowed; dorsal ridge not very prominent; 8·2 mm. long, 4 mm. broad, 3·5-3·7 mm. thick.

5. **Poulard à six rangs.**—A winter form received from France.

Young shoots, semi-erect; young leaves pubescent.

Straw, tall, 127 cm. (about 50 inches) high; upper internode hollow with thick walls.

Ear, 6-8 cm. long, very dense, compressed, 11-12 mm. across the face, 14-15 mm. across the side; spikelets 28-31, 3- to 4-grained; D=38-45; awns slender, 10 cm. long, sometimes deciduous (Ear type 2, Fig. 158).

Empty glume, 7 mm. long, apical tooth acute, 1 mm. long (2, Fig. 152).

Grain, mealy, plump, yellowish-red, dorsal ridge prominent; 7-7·5 mm. long, 3·5-4 mm. broad, 3·5-4 mm. thick.

Ear bearded, branched; glumes white, glabrous; awns white; grain red.

T. turgidum, var. **columbinum**, Körn. *Handb. d. Getr.* i. 63 (1885).

The form of var. *gentile* with compound ears.

Ear bearded, simple; glumes white, glabrous; awns black; grain white.

T. turgidum, var. **melanatherum**, Körn. und Wern. *Handb. d. Getr.* ii. 396 (1885).

T. turgidum, var. *nemausense*, Wittmack *ex* Körn. *Handb. d. Getr.* i. 59 (1885).

The empty glumes usually have a narrow black line along the outer margin, or are more or less blotched all over with black pigment. This variety has a wide range of cultivation, being grown in considerable amount in Italy, Spain, Greece, and the Baku Province of Transcaucasia, and to a lesser extent in France.

1 2

FIG. 156.—RIVET WHEAT (*T. turgidum*, L.).

1. var. *iodurum*. (Blue Cone.)

2. var. *Mertensii*. Greece.

Körnicke received samples as "Giant wheat" from an exhibition in Denver, Colorado, U.S.A.

A dense-eared form of wheat from Baluchistan has been referred to var. *melanatherum* by Howard.

The **Blé Garagnon du Languedoc**, cultivated in the south and north-west of France, is a form of this variety or of var. *nigrobarbatum*.

1. Received from Italy and Greece.

Young shoots, semi-erect; young leaves pubescent.

Straw, tall, 130 cm. (about 51 inches) high; upper internode hollow.

Ear, long and lax, 9-10·5 cm. long, square, 12-13 mm. across the sides; spikelets 22-24, 3-grained; D = 25-28; awns 14-15 cm. long (Ear type 1, Fig. 158).

Empty glume, 9 mm. long, with a black line along the outer margin; apical tooth short and blunt (1, 8, Fig. 152).

Grain, mealy, large, dorsal ridge prominent; 8 mm. long, 4 mm. broad, 3·9 mm. thick.

2. **Carosellone del Molise.**—A well-marked form received from Italy; similar forms also from Spain and Greece.

A form from Spain under this name has red grains (see below, var. *nigrobarbatum*, Desv.).

Young shoots, erect or semi-erect; young leaves pubescent.

Straw, tall, 132 cm. (about 52 inches) high; upper internode hollow with thick walls.

Ear, 6·5-8 cm. long, dense, compressed, 10-12 mm. across the face, 15 mm. across the 2-rowed side; spikelets 23-25, 2- to 3-grained; D = 38-44; awns 9-10 cm. long, black at the base, the upper half pale (Ear type 1, Fig. 158).

Empty glume, 7 mm. long, apical tooth acute, in some cases blunter, 1-2 mm. long (Forms 1, 4, Fig. 152). Sometimes the glume is entirely white; usually, however, there is a narrow black line along the outer margin, and in some seasons the dark pigment spreads over the rest of the glume; these colour variations are found in plants raised from a single ear.

Grain, mealy, apex truncate, dorsal hump prominent, radicle end sometimes dark brown; 7-8 mm. long, 3·5-4 mm. broad, 3·5-4 mm. thick.

Ear bearded, simple; glumes white, glabrous; awns black; grain red.

T. turgidum, var. **nigrobarbatum**, Körn. *Handb. d. Getr.* i. 60 (1885).

Körnicke obtained this variety from Spain, and Werner mentions its cultivation in the south of France.

Flaksberger states that a winter form of it is found in the Tiflis and Baku Provinces of Transcaucasia.

I have had it from Greece, Spain, and the United States.

1. **Phillipino**, received from the United States of America, and forms sent from Spain and Greece, belong to this variety.

Young shoots, semi-erect; young leaves pubescent.

Straw, tall, 132 cm. (about 52 inches) high; upper internode solid or hollow with thick walls.

Ear, 8-9 cm. long, usually square, 12-15 mm. across the sides; small ears much compressed, 9-10 mm. across the face, 12-14 mm. across the side; spikelets 22-25, 3- to 4-grained; D = 28-32; awns 12-13 cm. long (Ear type 2, Fig. 157).

Empty glume, 8-9 mm. long, with a black line along the outer margin, or, in some seasons, more or less uniformly black; apical tooth 2 mm. long, acute, broad at the base (1, Fig. 152).

Grain, more or less flinty, dorsal ridge prominent; 7·6 mm. long, 4 mm. broad, 3·5 mm. thick.

2. A form from Spain under the name **Carosellone del Molise**, with short dense grain similar to those of Carosellone del Molise (var. *melanatherum*) from Italy.

Ear bearded, branched; glumes white, glabrous; grain red; awns black.

T. turgidum, var. **pavoninum**, Körn. *Handb. d. Getr.* i. 63 (1885).

The form of var. *nigrobarbatum* with compound ears.

Ear bearded, simple; glumes white, pubescent; awns white; grain white.

T. turgidum, var. **megalopolitanum**, Körn. *Handb. d. Getr.* i. 60 (1885).

A rare variety found by Körnicke in a seedsman's sample of "Greek wheat from Megalopolis," and also in samples from Italy.

Ear bearded, simple; glumes white, pubescent; awns white; grain red.

T. turgidum, var. **buccale**, Körn. *Handb. d. Getr.* i. 60 (1885).

Körnicke states that var. *buccale* is cultivated in Germany, England, France, Spain, and Italy; I have also received it from Portugal.

The Cone Rivet or Anti-fly wheat formerly grown in England was a form of this variety.

1. **Pombinho.**—Received from Portugal.

Young shoots, semi-erect; young leaves pubescent.

Straw, tall, 132 cm. (about 52 inches) high; upper internode hollow with thick walls.

Ear, 7-9 cm. long, square, 12-14 mm. across the sides, or slightly compressed, 10 mm. across the face and 12-13 mm. across the side; spikelets 21-25, 3- to 4-grained; D = 28-30; awns stout, 12-15 cm. long (Ear type 2, Fig. 157).

Empty glume, 8 mm. long, apex narrow, apical tooth acute, 1 mm. long (Form 6, Fig. 152).

Grain, flinty or semi-flinty, dark red, truncate; dorsal ridge prominent; 7·3 mm. long, 3·6 mm. broad, 3·6 mm. thick.

2. **Sicilio**, with very villose glumes and short starchy grains, also from Portugal, closely resembles (1).

1 2

Fig. 157.—Rivet Wheat (*T. turgidum*, L.).

1. var. *nigrobarbatum*. (Phillipino.)

2. var. *Mertensii*. (Moula Oglau.)

Ear bearded, branched ; glumes white, pubescent ; awns white ; grain red.

T. turgidum, var. **centigranum**, Körn. *Handb. d. Getr.* i. 63 (1885).

The form of var. *buccale* with compound ears, the result of a cross and not constant (Körnicke).

Ear bearded, branched ; glumes white, pubescent ; awns white ; grain reddish-violet.

T. turgidum, var. **modigenitum**, Körn. *Arch. f. Biontologie*, ii. 403 (1908).

A form originating from grains of *T. durum*, var. *Schimperi*, apparently the product of a cross with a white, villose, branched ear of *T. turgidum* (Körnicke).

Ear bearded, simple ; glumes white, pubescent ; awns black ; grain white.

T. turgidum, var. **Salomonis**, Körn. *Handb. d. Getr.* i. 61 (1885).

A comparatively rare variety, the type of which was obtained by Körnicke from a sample of " Grano tenere bianco," sent by G. Salomone from Catania, Sicily, to the Vienna Exhibition in 1873.

A short dense-eared wheat from Baluchistan has been referred to this variety by Howard.

Ear bearded, simple ; glumes red, glabrous ; awns red ; grain white.

T. turgidum Dreischianum, Körn. *Handb. d. Getr.* i. 60 (1885).

Körnicke's type was sent to him under the name " Frumento bianco " by Dr. Dreisch from the Italian Exhibition held in Paris in 1878. This variety is chiefly confined to the Balkan area, most examples being received from Greece, Bulgaria, and Turkey.

A winter form from Greece, Bulgaria, and Turkey.

Young shoots, prostrate or semi-erect ; young leaves pubescent.

Straw, tall, 130 cm. (about 52 inches) high, hollow with thick walls.

Ear, 9-11 cm. long, lax, narrow, square, 10-11 mm. across the sides ; spikelets 22-24, somewhat elongated, 2- to 3-grained ; D = 22-24 ; awns about 13-14 cm. long, parallel to the sides of the ear (Ear type 2, Fig. 156).

Empty glume, 9 mm. long, apex narrow, apical tooth very short and blunt (3, 6, Fig. 152).

Grain, mealy, large, apex truncate, dorsal ridge prominent; 8·5 mm. long, 4·2-4·4 mm. broad, 3·65 mm. thick.

Ear bearded, branched ; glumes red, glabrous ; awns red ; grain white.

T. turgidum, var. **pseudocervinum**, Körn. *Handb. d. Getr.* i. 63 (1885).

This is one of the most frequently cultivated varieties with compound ears, and may be considered as var. *Dreischianum* with a branched rachis.

I have received examples from Turkey under the name **Keupely**, from Idaho and other parts of the United States as **Alaska**, **Seven-headed**, and **Miracle** wheat, and from Greece.

Young shoots, semi-erect; young leaves pubescent.

Straw, tall, 125-130 cm. (about 50 inches) high, hollow with thick walls. The plants tiller very little, each usually sending up not more than two straws.

Ears, 8-9 cm. long, varying in width according to the amount of branching.

In a typical ear (1, Fig. 160), which is generally less compound than var. *mirabile* (p. 256), the upper third is normal, bearing single spikelets at each notch of the rachis. At each notch of the middle third of the ear two spikelets arise, side by side, arranged at right angles to the spikelets above; the notches of the lower part of the ear bear short secondary ears, 2-2·5 cm. long, usually composed of 3-7 spikelets. A well-grown ear possesses 60-70 spikelets, yielding 90-100 small grains.

Empty glume, pale red, 6 mm. long; apical tooth very short and blunt; awns of the flowering glume 2·5-7 cm. long (9, Fig. 152).

Grain, small, semi-flinty, laterally compressed, with narrow apex; 6·7 mm. long, 3·5 mm. broad, 3·55 mm. thick.

A form of *pseudocervinum* is recorded by Körnicke and Werner from Castile Spain, under the name **Trigo Rubio**; they state that it is sometimes cultivated in Southern Europe and Northern Africa.

Ear bearded, simple; glumes red, glabrous; awns red; grain red.

T. turgidum, var. **speciosum**, Körn. *Handb. d. Getr.* i. 60 (1885).

A fairly common variety cultivated in Italy and France. Flaksberger records its occurrence from the Tiflis and Baku Provinces of Transcaucasia, and notes that pure lines of the typical red-awned variety sometimes give black-awned forms (var. *Mertensii*).

1. A winter form from Spain.

Young shoots, prostrate or semi-erect; young leaves pubescent; hairs short.

Straw, tall, 122 cm. (about 48 inches) high; upper internode solid.

Ear, lax, 9-10 cm. long, compressed, the face broader than the side as in *T. vulgare*, 12-15 mm. across the face, 10-11 mm. across the 2-rowed side; spikelets 21-23, broad, 3- to 4-grained; D = 23-25; awns 15 cm. long.

Empty glume, 9 mm. long, narrow, apical tooth acute.

Grain, flinty, narrow, dorsal ridge prominent; 7·8-7·9 mm. long, 3·7-3·9 mm. broad, 3·8-4 mm. thick.

2. **Mazzochio.**—A form grown extensively in Italy (Tuscany).

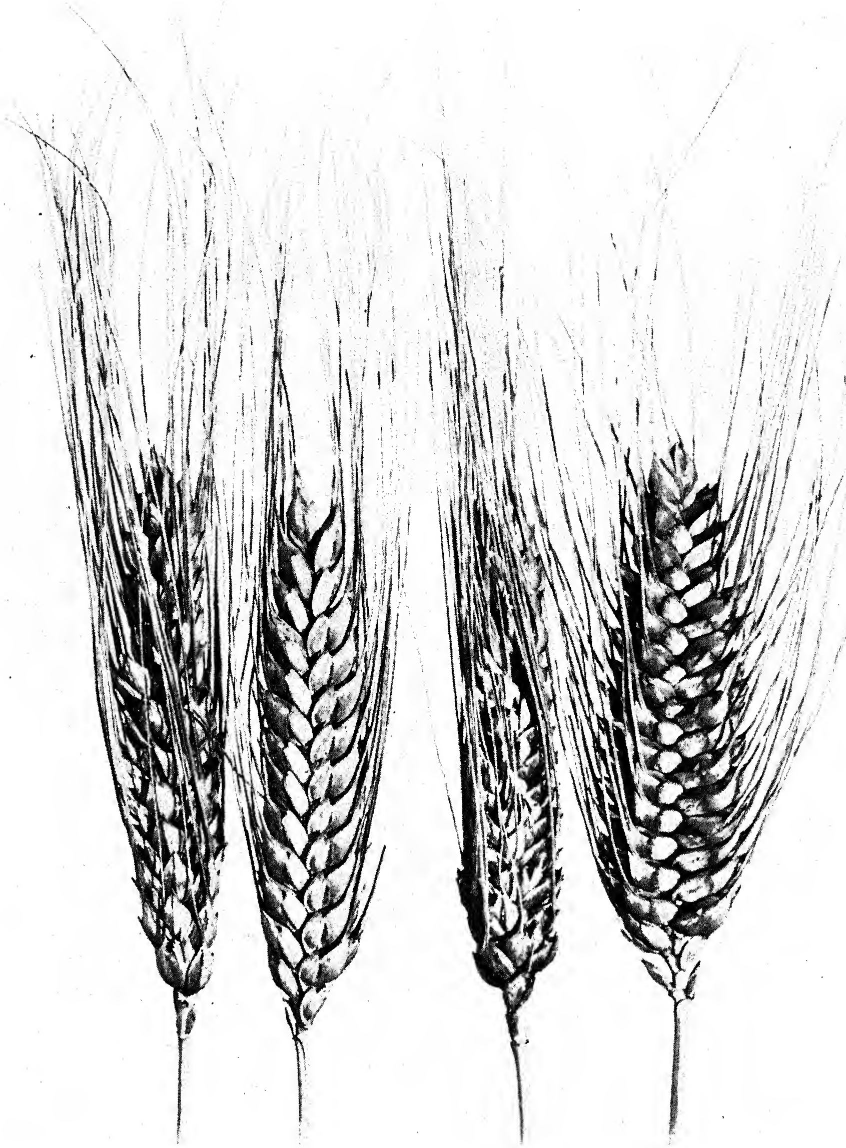
Young shoots, semi-erect; young leaves pubescent.

Straw, very tall, somewhat slender, 157 cm. (about 62 inches) high; upper internode solid.

Ear, 8-9 cm. long, square, 11-13 mm. across the sides, or slightly compressed, 10 mm. across the face and 12-14 mm. across the side; spikelets 22-25, 2- to 3-grained; D = about 30; awns stout, 12-15 cm. long, deciduous (Ear types 1, 2, Fig. 157).

Empty glume, 6-7 mm. long, apical tooth very short, blunt (3, 6, Fig. 152).

Grain, mealy, large, yellowish-red, dorsal ridge prominent; 8·2 mm. long, 4·5 mm. broad, 4 mm. thick.



1 2

FIG. 158.—RIVET WHEAT (*T. turgidum*, L.).

1. var. *melanatherum*.
(Carosellone del Molise.)

2. var. *gentile*.
(Poulard à six rangs.)

Poulard rouge de Gatinais, cultivated in the Central Departments of France, is a form of *speciosum* nearly allied to this.

3. **Buca vera.**—A winter form received from Haage and Schmidt, Erfurt, Germany.

Young shoots, prostrate; young leaves pubescent.

Straw, tall, 130 cm. (about 51 inches) high; upper internode hollow with very thick walls.

Ear, 9-10 cm. long, square, 12 mm. across the sides; spikelets short and wide, 22-25, 3- to 4-grained; D=about 30; awns slender, 10-11 cm. long, deciduous (Ear type 1, Fig. 156).

Empty glume, 7 mm. long, often with a dark line along the outer margin; apical tooth acute, curved, with a broad base, 1·5 mm. long (Form 4, Fig. 152).

Grain, mealy, dorsal ridge not prominent; 7·6 mm. long, 3·75 mm. broad, 3·4 mm. thick.

Ear bearded, branched; glumes red, glabrous; awns red; grain red.

T. turgidum, var. **cervinum**, Körn. *Handb. d. Getr.* i. 63 (1885).

A rare form derived from a cross.

Ear bearded, simple; glumes red, glabrous; awns black; grain white.

T. turgidum, var. **speciosissimum**, Körn. *Handb. d. Getr.* i. 60 (1885).

Körnicke obtained his type from a mixed sample of wheat designated "Frumento veneto" at the Italian Exhibition held in Paris in 1878. According to Flaksberger, this variety is cultivated in considerable amount in Transcaucasia. I received samples from Turkey.

A winter form received from Dr. Regel, Petrograd, from the district of Tiflis, Transcaucasia, and in a sample from Turkey under the name **Moula Oglau** (var. *Mertensii*).

Young shoots, prostrate; young leaves pubescent.

Straw, very tall, 150 cm. (about 60 inches) high; upper internode hollow with thick walls.

Ear, 8-10 cm. long, compressed, 9-11 mm. across the face, 13-14 mm. across the side; spikelets 23-27, 2- to 3-grained; D=29-31; rachilla with conspicuous fulvous hairs; awns 10-13 cm. long, jet black, parallel to the sides of the ears (Ear type 1, Fig. 157).

Empty glume, 7·5-8 mm. long, apical tooth short, blunt (6, 7, Fig. 152).

Grain, mealy, short, apex truncate, dorsal ridge prominent; about 7 mm. long, 4 mm. broad, 3·8 mm. thick.

Ear bearded, branched; glumes red, glabrous; awns black; grain white.

T. turgidum, var. **Plinianum**, Körn. *Handb. d. Getr.* i. 63 (1885).

The form of var. *speciosissimum* with compound ears. It is recorded by Flaksberger from Turkestan.

Ear bearded, simple ; glumes red, glabrous ; awns black ; grain red.

T. turgidum, var. **Mertensii**, Körn. *Handb. d. Getr.* i. 60 (1885).

Körnicke's type in the Berlin Herbarium has a dense square ear 7 cm. long and awns 15 cm. long. It was collected by G. Mertens in 1818 at " Vetrego nella campagna di Gottardo " as " Frumento faro o vicentin."

A comparatively uncommon variety chiefly found in the Balkan area. I have received samples from Turkey and Greece, and Flaksberger records the occurrence of dense-eared winter forms of this variety in Transcaucasia.

Moula Oglau.—A winter form received from Turkey and a similar form from Greece.

Young shoots, prostrate ; young leaves pubescent.

Straw, tall, 140 cm. (about 55 inches) high ; upper internode hollow with thick walls.

Ear, 8-10 cm. long, compressed, 10 mm. across the face, 13 mm. across the side ; spikelets 22-26, 2- to 3-grained ; D=28-30 ; awns 9-10 cm. long, upper part red, lower part black (Ear type 1, Fig. 157).

Empty glume, 8 mm. long, apical tooth blunt (3, 6, Fig. 152).

Grain, mealy, dorsal ridge not very prominent ; 7-8 mm. long, 4 mm. broad, 3·8 mm. thick.

Ear bearded, simple ; glume red, pubescent ; awn red ; grain white.

T. turgidum, var. **pseudomirabile**, mihi.

A rare variety received only from Spain.

Trigo Salmeron.—A form with long, narrow, very lax ears, which when young are a yellow-green tint.

Young shoots, erect or semi-erect ; young leaves with short hairs.

Straw, stout, tall, 120-135 cm. (48-53 inches) long ; upper internode solid.

Ear, long, lax, and narrow, 10-12 cm. long, square, 10-11 mm. across the sides ; spikelets 22-27, 3-grained ; D=22-24 ; awns 12-14 mm. long, scabrid to the base (Ear type 2, Fig. 159).

Empty glume, short, somewhat inflated, 8-9 mm. long ; apical tooth short and curved (18, Fig. 138).

Grain, white, opaque, with prominent dorsal hump ; 8·2-8·9 mm. long, 3·8 mm. broad, 3·8 mm. thick.

Ear bearded, branched ; glumes red, pubescent ; awns red ; grain white.

T. turgidum, var. **mirabile**, Körn. *Handb. d. Getr.* i. 63 (1885).

This is the most commonly grown variety having compound ears, being met with in the British Isles, France, Germany, Italy, Spain, Portugal, and the North African coast. In most instances it is cultivated on a small scale more as a curiosity than a profitable farm crop.

Miracle or **Mummy Wheat** (2, Fig. 160).—The commonest branched form of *T. turgidum*. Its massive ear suggests a high yield, but in field culture the return per acre from it is low except on rich soil in a warm climate.

1 2

FIG. 159.—RIVET WHEAT (*T. turgidum*, L.).

1. var. *dinurum*. (Red Rivet.) 2. var. *rubro-atrum*.

Young shoots, semi-erect ; young leaves almost smooth, the hairs on the ridge being reduced in this form to short projections from the epidermis.

Straw, tall, 125-130 cm. (about 50 inches) high ; upper internode solid.

Ear, compressed, 7-9 cm. long, and 4-5 cm. across the widest part. The branching of the ear is hereditary, but the extent of its manifestation is influenced by soil conditions and season and by the space allotted to the plants.

In the simpler, least compound ears the upper part is normal, with a single spikelet at each notch of the rachis, a few of the lower notches producing a pair of spikelets placed side by side and arranged at right angles to those of the normally placed single spikelets above. In large well-developed ears the upper third is usually normal ; below this, one or two notches bear pairs of spikelets ; at the remaining lower notches secondary ears are produced, their spikelets being arranged at right angles to those on the apical portion of the main axis. The secondary ears vary in number, length, and development ; ten or twelve are often found on well-grown ears, the largest 3-4 cm. long with 10-14 small crowded spikelets, whose grains often protrude from between the short glumes ; the basal secondary ears are often rudimentary, possessing 4-10 diminutive spikelets, usually barren or nearly so.

A large well-developed ear frequently has a total of 115-120 spikelets and 140-150 grains, one of average size 85-90 spikelets and 80-100 grains ; the wheat is nevertheless not prolific in field culture, the tillering power being low, each plant rarely producing more than two straws.

Empty glume, 7 mm. long, reddish, with a glaucous covering and a dark line often along the outer margin (Forms 4, 6, Fig. 152). The awns of the flowering glumes are short and slender, 4-9 cm. long, sometimes black at the base.

Grain, mealy, small, with prominent dorsal ridge and blunt apex ; 6·5 mm. long, 3·8 mm. broad, 3·8 mm. thick.

Ear bearded, simple ; glumes red, pubescent ; awns red ; grain red.

T. turgidum, var. **dinurum**, Körn. *Handb. d. Getr.* i. 63 (1885).

This is perhaps the most widely cultivated variety of *T. turgidum*, some forms being comparatively hardy and adapted to a great range of climate. It is grown in England, France, Germany, Italy, Spain, Portugal, Bulgaria, Greece, and Turkey ; apparently not in Russia. The young leaves of the majority of the representatives of this variety are almost glabrous, the hairs being very short, from 32 to 64 μ long, those of typical *turgidum* being 120-250 μ long.

1. **Trigo focense.**—Received from Spain. (I have had forms of *T. vulgare*, var. *erythrospermum*, from Spain under the name Trigo focense.)

Young shoots, semi-erect ; young leaves almost glabrous.

Straw, very tall, 150 cm. (about 60 inches) high ; upper internode hollow with thick walls.

Ear, lax, 10-12 cm. long, *vulgare*-like, 12-15 mm. across the face, 10-11 mm. across the 2-ranked side ; spikelets 26-30, wide, 3- to 4-grained ; D = 26-27 ; awns 12-13 cm. long, deciduous (Ear type 1, Fig. 156).

Empty glume, 8 mm. long, apical tooth acute, 1·5 mm. long (4, Fig. 152).

Grain, flinty, large, dorsal ridge prominent, apex truncate; 7·5 mm. long, 3·7 mm. broad, 3·7 mm. thick.

2. **Nonette de Lausanne.**—Received from France; cultivated in Italy under the name **Andriolo rosso pelosa.**

A winter form grown formerly in England under the name **Giant St. Helena wheat**. It is a prolific wheat, fairly resistant to frost and grows satisfactorily on comparatively poor strong soils.

Young shoots, semi-erect; young leaves almost glabrous.

Straw, very tall, stout, 152 cm. (about 60 inches) high; upper internode hollow.

Ear, of medium density, pendent when ripe, 8-9·5 cm. long, square, 12-14 mm. across the sides; spikelets 27-31, 3- to 4-grained; D=29-32; awns 9-10 cm. long (Ear type 1, Fig. 156).

Empty glume, 8 mm. long, with acute apical tooth, 1·5-2 mm. long, and distinct lateral tooth (Forms 1, 4, Fig. 152).

Grain, more or less flinty, long and somewhat narrow with indistinct dorsal ridge; 8·3 mm. long, 3·9 mm. broad, and 3·6 mm. thick. Closely similar forms were received from Bulgaria and Greece and from the United States under the name **Ratel**, and as **Gigante Milanese** from Italy, France, and Spain.

3. A form received from Turkey under the name **Hudavendigar** resembles the preceding, but has narrower, square ears 9-11 mm. across the sides, divergent awns, and smaller semi-flinty grains narrowed at the apex, with a prominent dorsal ridge; 6·8-7 mm. long, 3·5-3·7 mm. broad, 3·5-3·8 mm. thick.

4. **Red Rivet; Clock Wheat.**

Young shoots, semi-erect; young leaves almost glabrous.

Straw, tall, stout, 130-132 cm. (about 52 inches) high; upper internode hollow with thick walls.

Ears, dense, 7·5-9 cm. long, square, 12-14 mm. across the sides; spikelets 28-36, 3- to 4-grained; D=38-40; awns divergent, 8-9 cm. long, pale red (Ear type 1, Fig. 159).

Empty glume, 6-7 mm. long, apex narrow; apical tooth narrow, acute, 1·5 mm. long (4, Fig. 152).

Grain, starchy, laterally compressed, dorsal ridge prominent; 7 mm. long, 3·45 mm. wide, 3·65 mm. thick.

The term Rivet is obscure; its first recorded use is by Tusser in his *Fiue hundred pointes of good Husbandrie* (ed. 1580; not in the first ed. 1573).

> White wheat or else red, red riuet or whight,
>   far passeth all other for land that is light,
> White pollard or red, that so richly is set:
>   for land that is heauie is best ye can get.
> . . . .
> So Turkey or Purkey wheat, many do loue:
>   because it is flourie as others aboue.

This wheat is often erroneously termed "Rivett's wheat," but the word rivet is correctly used in the plural—rivets—in a generic sense for this and other varieties of *turgidum* or samples of their grain. Red Rivet wheat also had various other names such as **Pendule** or **Pendulum** wheat (doubtless on account

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FIG. 160.—RIVET WHEAT (*T. turgidum*, L.).

1. var. *pseudocervinum*. (Alaska or Seven-headed.)

2. var. *mirabile*. (Miracle or Mummy.)

of its drooping ears), **Red Cone** or **Red Pollard** wheat, though Tusser implies that Red Pollard was different from Red Rivet; **White Rivet** is also mentioned by Worlidge (1681).

Neither this nor the previously mentioned forms of var. *dinurum* are much grown in England at the present day, their place being taken by forms of var. *iodurum*, to which the generic term *Rivet* is frequently applied.

A sample of wheat received from Germany under the name **Payne's Defiance** consisted of Red Rivet and Blue Cone (see p. 260).

Ear bearded, branched; glumes red, pubescent; awns red; grain red.

T. turgidum, var. **Linnaeanum**, Körn. *Handb. d. Getr.* i. 63 (1885).
The rare form of var. *dinurum* with compound ears.

Ear bearded, simple; glumes red, pubescent; awns black; grain red.

T. turgidum, var. **rubroatrum**, Körn. *Handb. d. Getr.* i. 61 (1885).

A rare variety found by Körnicke among other wheats from Italy. I received a narrow lax-eared form of this variety from Spain; some of its characters suggest a relationship to *T. vulgare*.

Young shoots, erect or semi-erect; young leaves slightly hairy.

Straw, of medium height, 90-100 cm. (38-40 inches) high; upper internode solid.

Ear, long, lax, and narrow, 10-11 cm. long, square, 10-11 mm. across the sides; spikelets 21-23, 3-grained; D = 22; awns 12 cm. long, scabrid to the base (Ear type 2, Fig. 159).

Empty glume, short, somewhat inflated, 8 mm. long; apical tooth short (Forms 2, 5, Fig. 152).

Grain, pale red, flinty, short, apex truncate, dorsal ridge prominent; 7·6-7·9 mm. long, 3·6-3·9 mm. thick.

Ear bearded, simple; glumes blue-black, glabrous; awns black; grain white.

T. turgidum, var. **Herrerae**, Körn. *Handb. d. Getr.* i. 60 (1885).

A rare variety the type of which was obtained by Körnicke from Valencia, Spain.

According to Vasilieff, it is grown in the Tiflis Province of Transcaucasia.

The **Blé Garagnon noir**, which Heuzé says is cultivated in Algeria and occasionally in the olive regions of France, appears to be a form of var. *Herrerae*.

Ear bearded, simple; glumes blue-black, pubescent; grain red.

T. turgidum, var. **iodurum**, Körn. *Handb. d. Getr.* i. 61 (1885).

In some forms of this variety the colour of the glume is a dense blue-black; in others, especially those with dense ears, it is a pale bluish-grey.

The ground tint in most cases is reddish, and when this tint preponderates, as it often does in damp seasons, the forms are difficult to separate from those of var. *dinurum*. The empty glumes of the pale forms of the var. *iodurum*,

however, usually have a dark outer margin. Like var. *dinurum* this is one of the most extensively cultivated varieties of *T. turgidum*, being adapted to a comparatively wide range of climate. It is grown in England, France, Germany, Italy, Spain, and Portugal, and occasionally in Australia and the United States of America. Flaksberger says it is not found in Russia.

1. **Pisana francesca.**—A distinct winter form received from Spain and Portugal; the flat-faced, narrow-sided ear suggests a relationship to *T. vulgare*.

Young shoots, prostrate; young leaves pubescent.

Straw, tall to very tall, 130-150 cm. (about 50-60 inches) high, hollow with thick walls.

Ear, 8-9 cm. long, 13-15 mm. across the face, 10-12 mm. across the side; spikelets broad, 22-24, 3- to 4-grained; D=24-27; awns divergent, 9-10 cm. long, deciduous (Ear type, Fig. 155).

Empty glume, short, inflated, blue-grey on a red ground, 6 mm. long; apical tooth curved, acute, 1 mm. long (4, Fig. 152).

Grain, mealy, pale yellowish-red, large, with prominent dorsal ridge; 7·5 mm. long, 4 mm. broad, 3·9 mm. thick.

Pole-rivet, formerly cultivated in England, appears to have been allied to this form.

2. **Pétianelle noire de Nice.**—A spring form received from France.

Young shoots, erect; young leaves pubescent.

Straw, very tall, 140 cm. (about 56 inches) high, striate; upper internode solid.

Ear, lax, 11-15 cm. long, square, narrow, 10-12 mm. across the sides; spikelets 26-30, 3- to 4-grained; D=22-27; awns 12-14 cm. long, deciduous when ripe (Ear types 1, 2, Fig. 156).

Empty glume, 7 mm. long, blue-black with a glaucous surface; apical tooth acute, broad at the base, about 1 mm. long (Forms 1, 4, Fig. 152).

Exposed parts of the flowering glume blue-black, the parts covered by the empty glumes pale yellowish-red.

Grain, more or less flinty, large, not always plump; 7·5 mm. long, 3·5 mm. broad, 3·8 mm. thick.

A distinct and striking form only suited to a warm climate.

Forte Nero from Italy and an unnamed form from Spain closely resemble Pétianelle noire de Nice, and "Andriolo nero" and **Grano nero** are synonymous Italian forms.

Very similar also is **Reynold's Discovery** received from Australia, with hollow straw and large flinty grain; 8·2 mm. long, 3·9 mm. broad, 3·9 mm. thick.

3. **Blue Cone.**—A winter form, a select line of which, introduced by the author, is grown in the southern half of England.

A similar form under the name **Poulard d'Australie** or **Poulard bleu** is grown in the north of France.

Young shoots, prostrate; young leaves pubescent; blades narrow.

Straw, very tall, 150 cm. (about 58 inches) high, striate; the upper internode hollow with thick walls.

Ear, pendulous when ripe, 9-10 cm. long, tapering a little towards the apex,

square, 12-14 mm. across the sides; spikelets 26-30, well filled, 3- to 4-grained; D = 30-32; awns 10-11 cm. long, deciduous (Ear type 1, Fig. 156).

Empty glume, 8 mm. long, blue-black on a reddish ground; in damp seasons the ear is pale ashy-brown or "mouse coloured"; apical tooth 1-1·5 mm. long (4, Fig. 152).

Grain, starchy, yellowish-red, plump, apex truncate, dorsal ridge prominent; 7·5-8 mm. long, 3·7 mm. broad, 3·65 mm. thick.

The term "Cone" applied to this and similar forms of *T. turgidum* probably refers to the slightly tapering conical ear, which results when the lower spikelets develop more and plumper grains than the upper.

Long Cone and **White Cone** wheats are mentioned by Plot in his *Natural History of Oxfordshire* in 1677, along with a **Red Cone** form called **Pendule wheat.**

Grey Cone or **Grey Pollard**, also called **Dugdale** and **Duckbill wheat**, grown frequently in the seventeenth and eighteenth centuries in England, was a form with shorter ears and reddish-grey glumes. The specimen labelled "Grey Pollard" in Petiver's Herbarium (British Museum) is about 7 cm. long, one of "Cone wheat" in the same collection being 8·5 cm. long.

A sample of Payne's Defiance from Germany consisted of Blue Cone and Red Rivet (var. *dinurum*).

Ear bearded, branched; glumes blue-black, pubescent; grain red.

T. turgidum, var. **coeleste.** *Handb. d. Getr.* i. 64 (1885).

From the cross *T. dicoccum*, var. *cladurum* × *T. turgidum*, var. *iodurum*, Körnicke obtained this variety and a similar beardless unbranched variety (var. *coelestoides*), neither of which was constant.

Ear beardless, simple; glumes blue-black, pubescent; grain red.

T. turgidum, var. **subiodurum**, Körn. *Arch. f. Biontologie*, ii. 401 (1908).

The product of a cross obtained by Gustav Bestehorn. Körnicke states that it is constant, and differs only from var. *iodurum* in possessing beardless ears.

CHAPTER XVIII

EGYPTIAN CONE WHEAT

Triticum pyramidale, mihi.

A SMALL race which I have seen only from Egypt. It has some of the characters of *T. turgidum*, but, unlike this, has short straw, characteristic yellow-green culm leaves, pointed grain, and is among the earliest wheats, coming into ear at Reading at the end of May or the first few days in June.

The Dwarf wheats collected by W. Schimper in Abyssinia and referred to *T. compactum* by Körnicke, doubtless belong to this race.

GENERAL CHARACTERS OF *T. pyramidale*, mihi.

The young plants have erect shoots ; the leaf-surface is clothed with soft hairs of equal length, like those of *T. dicoccum* and *T. turgidum*.

The straw is very short, rarely more than 80-100 cm. (32-40 inches) high, solid or hollow with thick walls.

The culm leaves are generally a yellow-green tint. The ears, which usually taper towards the apex, are short and very dense, rarely measuring more than 5 or 6 cm., and having a density usually over 40 ; spikelets 20-23.

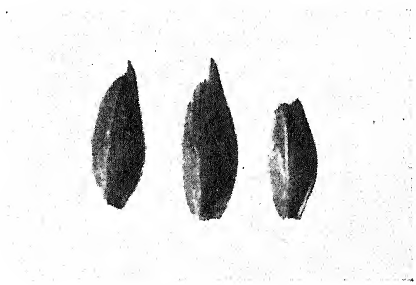


FIG. 161.—Empty glumes of Egyptian Cone wheat (*T. pyramidale*) (× 2).

The edges of the rachis are fringed with conspicuous white hairs, and there is a frontal tuft at the base of each spikelet.

The spikelets are about 12 mm. long and 12 mm. wide, and often ripen 3 or 4 grains in each.

The empty glumes are strongly keeled from the tip to the base ; the apical tooth in some forms is long and acute, in others short and blunt (Fig. 161).

The flowering glume bears a long, somewhat slender awn from 9 to 15 cm. in length, which is scabrid to the base.

The grains are a fine white tint, generally mealy, laterally compressed, narrowed at the apex, with a prominent dorsal ridge or hump; they are 7·5-8·5 mm. long, 3·3 mm. broad, and 3·5-3·6 mm. thick (Fig. 162).

VARIETIES OF *T. pyramidale*, mihi.

1. Ear bearded; glumes white, glabrous; awns white . var. *recognitum*, mihi.
2. Ear bearded; glumes white, pubescent; awns white . var. *compressum*, mihi.
3. Ear bearded; glumes white, pubescent; awns black. var. *pseudo-compressum*, mihi.
4. Ear bearded; glumes pale red, pubescent; awns red . . . . . var. *copticum*, mihi.
5. Ear bearded; glumes pale red, pubescent; awns black . . . var. *pseudo-copticum*, mihi.

FIG. 162.—Grains of the spikelets of one side of an ear of Egyptian Cone wheat (*T. pyramidale*) (nat. size).

Ear bearded; glumes white, glabrous; awns white; grain white.

T. pyramidale, var. recognitum, mihi.

White Saidi (1, Fig. 163).—An early wheat received from Upper Egypt.

This is a very distinct form, referred by Seringe to *T. durum complanatum* and described by Delisle (*Descr. de l'Egypte*, ii. 177) as *T. sativum pyramidale*. Körnicke's *T. compactum*, var. *recognitum*, is probably this form.

In its habit and the morphological characters of its leaves, it is quite unlike *T. durum*, *T. sativum*, or *T. compactum*.

Young shoots, erect; young leaves pubescent, the hairs slightly shorter in this than in most varieties of *T. dicoccum*.

Straw, short, 80-85 cm. (about 33 inches) high; upper internode hollow with thick pithy walls.

Ear, short and very dense, 4·5-5 cm. long, 10-11 mm. across the face, 15-18 mm. across the side; spikelets 20-21, densely crowded on the rachis, many with three grains in each; D=45-50. Awns about 11 cm. long, scabrid to the base. The ear is flattish on one side and convex on the other. It tapers from the base towards the apex, which in the larger ears is often curved to one side.

Empty glume, 8 mm. long; apical tooth broad and blunt, 1 mm. long (3, Fig. 161).

Grain, mealy, dorsal hump very prominent; 7·5 mm. long, 3·3 mm. broad, 3·65 mm. thick.

Ear bearded ; glumes white, pubescent ; awns white ; grain white.

T. pyramidale, var. **compressum**, mihi.

This variety I obtained from Egypt mixed with the succeeding variety, from which it differs only in the colour of the awn.

Ear bearded ; glumes white, pubescent ; awns black ; grain white.

T. pyramidale, var. **pseudo-compressum**, mihi.

A form of this variety I received from Egypt under the names **Tunis wheat** and **Fayum wheat.**

It is an early, short-strawed form, with the characteristic dense ear of the race.

Körnicke's *T. compactum*, var. *compressum*, appears to be the same.

Young shoots, erect ; young leaves pubescent.

Straw, short, rigid, 56-80 cm. (22-32 inches) long; upper internode solid hollow with thick walls.

Ear, short and dense, 4-6 cm. long, oblong in section, 10-11 mm. across the face, 15-18 mm. across the 2-rowed side ; spikelets 21-23, 3-grained ; D = 40-43.

Empty glume, 9-10 mm. long, apex narrow, apical tooth acute (2, Fig. 161); awn of flowering glume 10-13 mm. long.

Grain, white, flinty or semi-flinty, narrow at the apex, laterally compressed, with a prominent dorsal ridge; 8-8·4 mm. long, 3·6 mm. broad, 3·5-3·6 mm. thick.

Ear bearded ; glumes pale red, pubescent ; awns red ; grain white.

T. pyramidale, var. **copticum**, mihi.

Ein el Bent (Eye of the Girl) (2, Fig. 163).—A distinct form received from Egypt, and probably the same as Körnicke's *T. compactum*, var. *copticum*, from Abyssinia.

Young shoots, erect ; young leaves pubescent.

Straw, short to medium height, 76-105 cm. (about 30-42 inches) high, glaucous ; upper internode hollow with thick walls.

Ear, yellow-green, short and compressed, dense, 5-8 cm. long, 12 mm. across the face, 20 mm. across the two-ranked side ; spikelets 20-25 ; D = about 36 ; awns 14-17 cm. long, scabrid to the base.

The ears usually taper from the base to the apex and are often curved towards the flat side near the tip.

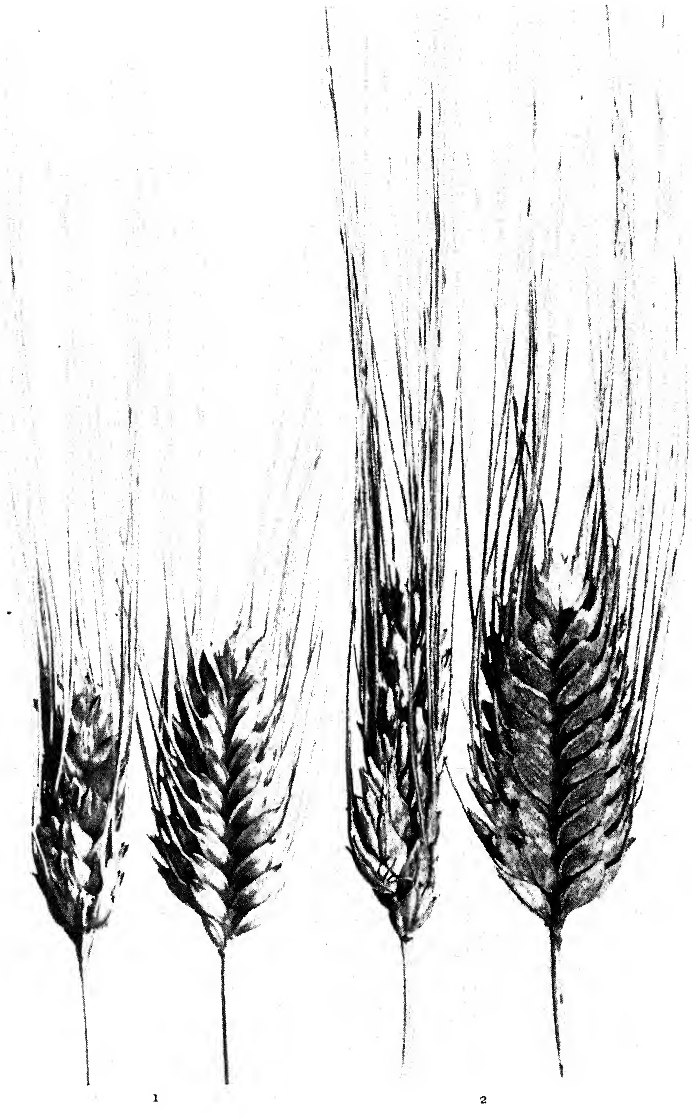
Empty glume, 10 mm. long, pale red, pubescent, with prominent lateral nerve ; keel tooth broad and bluntish (1, Fig. 161).

Grain, white, semi-flinty, laterally compressed, with prominent dorsal hump ; 6·5-7·5 mm. long, 2·8-3·2 mm. broad, 3·3-3·6 mm. thick.

Ear bearded ; glumes pale red, pubescent ; awns black ; grain white.

T. pyramidale, var. **pseudo-copticum**, mihi.

Received with the preceding variety, from which it differs only in the possession of black awns.



1 2

FIG. 163.—EGYPTIAN CONE WHEAT (*T. pyramidale*, mihi).

1. var. *recognitum*. (White Saidi.)

2. var. *copticum*. (Ein el Bent.)

CHAPTER XIX

COMMON BREAD WHEAT

Triticum vulgare, Host. *Icon. et descr. Gram. Aust.* iii. 18 (1805).
T. aestivum, L. (bearded). } *Sp. Pl.* 85, 86 (1753).
T. hybernum, L. (beardless). }
T. sativum, Lamk. *Ency. Meth.* ii. 554 (1786).
= { *T. aestivum*, L.
T. hybernum, L.
T. turgidum, L. }
T. vulgare, Vill. (= *T. aestivum*, L.). *Hist. Pl. d. Dauph.* ii. 153 (1787).
T. sativum, Pers. *Syn. Pl.* i. 109 (1805):
α. *aestivum.* | β. *hybernum.* | γ. *durum.*

ALTHOUGH bread can be made from Macaroni (*T. durum*), Rivet (*T. turgidum*), and other wheats, it is from *Triticum vulgare* that the world's bread is chiefly produced. The peculiar physical quality of the gluten of its grain specially fits it for the manufacture of spongy, digestible bread, and in this respect it surpasses all other races. In addition, on account of its great adaptability to a variety of climatic conditions, it is the most widely distributed of all. More of this race is grown than of any other, some forms of it being found in every country wherever wheat of any kind is cultivated.

Bread wheat is one of the most ancient of cereals, examples of ears of grain in considerable abundance having been discovered in various parts of Europe on sites occupied by man in Neolithic times and the Bronze and Iron Ages.

In the earliest periods the grains were distinctly smaller than the forms now cultivated, but all grades up to the large plump grains near to those of *T. turgidum* are met with in the later deposits.

The most primitive of prehistoric wheats of this race appears to be a variety hitherto found only in the Neolithic store-chambers at Lengyel (Hungary) and described by Deininger under the name *T. sativum Scythicum*. In this form the apex of the grain tapers to a narrow point, the whole being pear-shaped, with little or no sign of a furrow on the ventral

side and more or less circular in transverse section. The grains measure 3·5-4·5 mm. long, 2-3 mm. broad, and 1·8-2·6 mm. thick.

Deininger infers that the spikelets of this wheat probably bore only one grain, and concludes that this form is the prototype of the Bread wheats and a form found more widely distributed throughout Europe in the Neolithic period named *T. vulgare antiquorum* by Heer. The ears of the latter are beardless, short, and dense (4-5 cm. long and 10 mm. wide), with three or four grains in each spikelet; the empty glumes are strongly keeled throughout their length with an inwardly curved apical tooth. The grain is especially small and blunt at the apex, and markedly convex on the dorsal side; the average dimensions are: length 5 mm., breadth 3·5 mm. Körnicke and Buschan place this wheat under *T. compactum*, a view in which I concur, the examples I have seen being most like some Chinese *compactums* of the present day.

It is not until the Bronze and Iron Ages that grains similar in size and form to those now cultivated became common in prehistoric deposits.

In Britain small-grained forms of *T. vulgare*, possibly mixed with those of *T. compactum*, were cultivated in Roman times.

I have seen no examples which can be attributed with certainty to this race from ancient Egypt, but the wheats described under the name πυρός by the Greeks and *triticum* by Roman authors were wheats with grain loosely invested by the glumes, and doubtless included *T. vulgare* as well as *T. durum*.

General Characters of *T. vulgare*

1 The young shoots are erect, semi-erect, or prostrate.

2 A number of forms from China, Japan, Persia, and India have yellowish-green leaves; the majority, however, have more or less glaucous blades and ears.

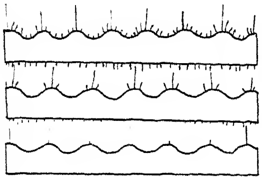


Fig. 164. — Diagrammatic transverse sections of young leaves of *T. vulgare*, *T. compactum*, *T. sphaerococcum*, *T. Spelta*.

3 On the surface of the young leaves hairs are always present. A characteristic single line of long hairs is found along the summit of all the longitudinal ridges or upon those near the leaf-margins; in some cases this is the only line of hairs present, others have in addition a number of shorter hairs covering the flanks of the ridges (Fig. 164).

4 The culms vary in height from 75 cm. (about 30 inches), or less in some Asiatic forms, to 140-150 cm. (55 or 60 inches). They possess 5 or 6 internodes, which are usually hollow, with comparatively thin walls, but in a few forms (*e.g.* New Zealand Tuscan) they are solid. 5 The ears are generally grouped into bearded

and beardless forms; a few Japanese and Australian forms are quite awnless, but most of the so-called beardless wheats have short awns on the flowering glumes of the upper spikelets of the ear, and in a few forms fine short awns of uniform length are found on all the flowering glumes.

6 In most varieties the ears are flattened and broadest across the face; sometimes the width across the 2-ranked side and the face is the same, but I have met with none in which the width of the 2-ranked side is uniformly greater than that of the face, as in many forms of *T. durum* and *T. turgidum*.

The length of the ear varies from 6 to 18 cm. (about 2·5-7 inches), with an average of 20 spikelets per ear, the density varying from 14 or 15 to 36 or more per 10 cm. of rachis.

7 The rachis is tough and smooth, and fringed with short hairs along its margins, with a few hairs immediately below the base of each spikelet.

The spikelets are 5- to 9-flowered; near the middle of the ear they not infrequently ripen 4 or 5 grains, but those near the base of the ear are often barren or contain 1 or 2 grains only; generally in the apical spikelets only 1 or 2 grains are developed.

8 The spikelets are 10-15 mm. long, 9-18 mm. across the face, and 4-5 mm. thick. The empty glumes are glabrous, pubescent, or villose, creamy-white, canary-yellow, or various shades of red, brown, or blue-black; those of the lateral spikelets are 6-11 mm. long, unsymmetrical, 3-5 mm. from the midrib to the outer edge, terminating in a tooth, which in the beardless forms is short and usually blunter than that of *T. durum*, and in the bearded form often prolonged into a slender awn from 1 to 3 cm. or more in length. The midrib is commonly prominent only in the upper half, but in some cases there is a well-developed keel running from the apex to the base of the glume; the various forms of the empty glume and their apical teeth are illustrated in Figs. 165 and 166.

9 The flowering glumes are thin and pale, rounded on the back with 7-11 nerves. In bearded wheats the awns are from 5 to 10 cm. long, triquetrous, scabrid, and persistent, and in some Chinese forms very fine, in others, especially Persian and Indian sorts, stout and brittle. They are generally of the same tint as the glume, namely, reddish- or yellowish-white, black or dark brown awns being of exceptional rarity in *T. vulgare*, though frequent in other races. The awns are usually straight or only slightly curved, but in some Asiatic wheats they are tortuose or bent into the form of a hook or loop (1, Fig. 179). A peculiar form is illustrated in Figs. 179 and 217.

The grains are white, yellow, pale orange, or varying shades of red or brown, the colour being most readily determined in those with mealy, opaque endosperm.

They are generally plump, somewhat broad and bluntish at the apex,

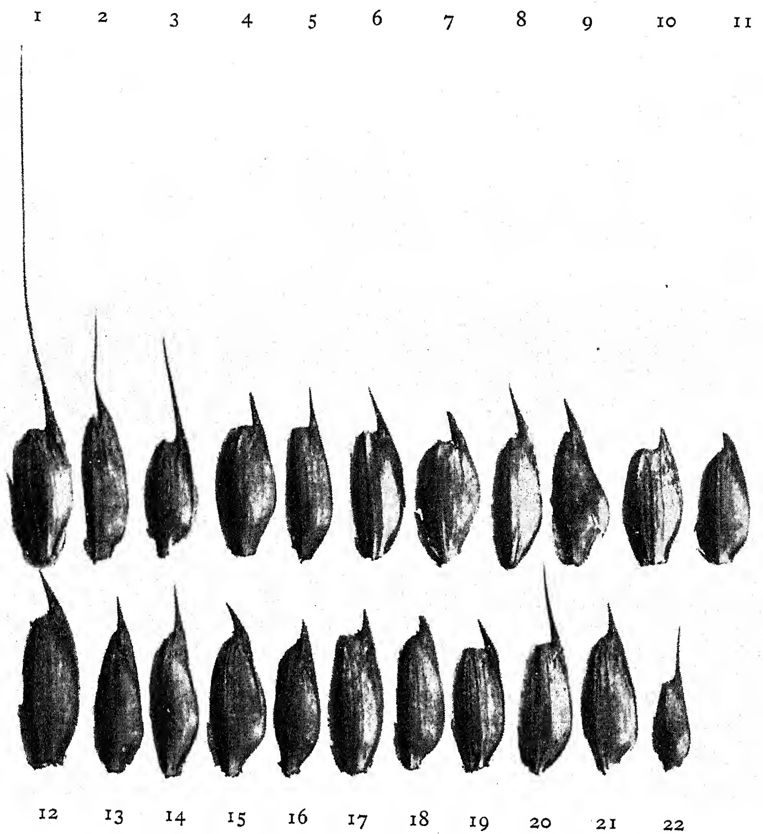


FIG. 165.—Empty glumes of bearded forms of Bread wheat (*T. vulgare*) (×2).

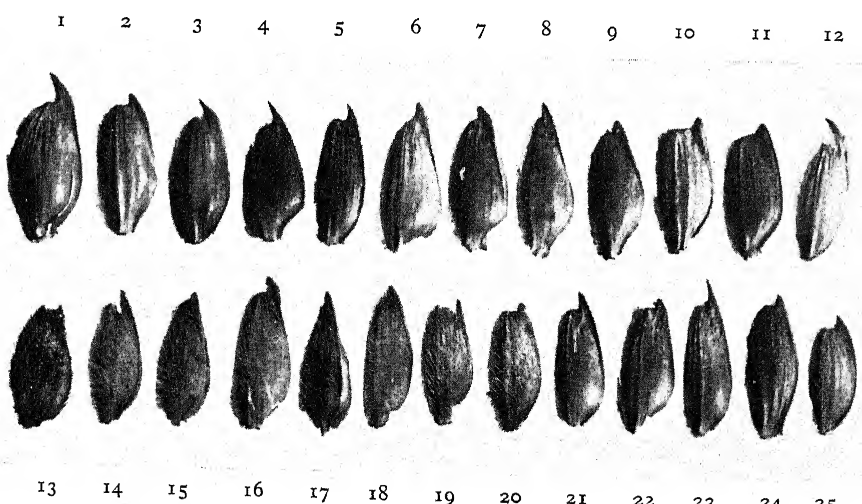


FIG. 166.—Empty glumes of beardless forms of Bread wheat (*T. vulgare*).

where there is a " brush " of hairs ; the furrow is usually shallow, and the cheeks on each side of it are convex and plump (Fig. 167).

The endosperm is flinty, semi-flinty, or completely mealy.

Measurements of grains taken from the middle of the ear of sixty forms gave the following results :

	Length.	Breadth.	Thickness.
	mm.	mm.	mm.
Average	6·78	3·63	3·25
Limits	5·2-8·5	2·9-4·2	2·6-3·9
Ratio	100	53·5	47·9

In number of its varieties and forms Bread wheat is the richest of the races of wheat. More than 1300 have been collected and studied for many

FIG. 167.—Grains of Bread wheats (*T. vulgare*); front, back, and side views (nat. size).

years at Reading. These exhibit an extraordinary diversity of morphological characters, as well as differences in habit of growth and period of ripening, and an almost unbroken series of transitional forms are found connecting the most widely different varieties.

Long lax ears pass insensibly into the short dense Squareheads, and in the form of the empty glume and the length of the awns of the flowering glumes similar gradation is observed. Even between the Spring wheats with erect young shoots and the prostrate Winter kinds forms are common with young shoots which spread outwards at intermediate angles.

There is little doubt that *T. vulgare* is a vast collection of mutants and hybrids, which I regard as having originated from the crossing of

T. dicoccoides or *T. dicoccum* with one or two species of *Aegilops* (see Chapter XXIII.).

The natural classification and description of such a series presents much the same problems and a similar degree of complexity as the classification of the human race, and nothing less than a minute description of individuals would adequately represent it.

The artificial classification into varieties presents no difficulty, and a few common forms of each variety are described later.

Some broadly outlined natural groups are readily recognised when the living plants are studied, although the lines of demarcation are in some cases obliterated by the normal fluctuating variations of the different forms composing them. Among such groups of apparently genetically related forms are the following :

FIG. 168.—Grains of the spikelets of one side of an ear of Bread wheat (*T. vulgare*) (nat. size).

GROUP I.—The endemic forms of *T. vulgare* from India and also several from Persia and Turkestan. These are all early, rapid-growing forms, which come into ear at Reading about the end of May or first week in June when sown in autumn or early spring ; under favourable climatic conditions many of them are able to produce ripe grain in one hundred days or less from the time of sowing.

The young shoots are erect, straw slender, inclined to curve towards the ground, in cool seasons short, 76-90 cm. (30-36 inches) high, in hotter years taller, leaves yellowish-green in the early, and more or less glaucous in the later forms.

The ears are often quadrate, short, or of medium length, from 6 to 10 cm. long, usually lax and rigid, with a somewhat brittle rachis. The density of "pedigree" lines in this group is more variable than in any other, especially when comparison is made between plants sown in autumn and those of the same line sown in spring.

The spikelets, 12-20, are sometimes arranged irregularly on the rachis, especially in the case of lax ears ; in the denser ears they overlap each other.

The empty glumes are rigid, scabrid, and not infrequently keeled to near the base ; in the bearded forms the awns of the flowering glumes are short (4-6 cm. long), scabrid, brittle, and divergent.

1

2

FIG. 169.—BREAD WHEAT (*T. vulgare*, Host).

var. *erythrospermum*.

1. (Rosso gentile aristata.) 2. (Wagia, Bombay.)

The grains, usually 3 or 4 per spikelet, are flinty or semi-flinty, very soft, mealy endosperm being uncommon ; they are held somewhat firmly in the glumes.

All forms of this group are very susceptible to attacks of Yellow Rust, which in England often damages the plants so much that few or no grains attain their full development.

GROUP II. Endemic Persian and Central Asiatic Wheats.—The young shoots are erect or semi-erect; the straw of medium height, somewhat thick and soft; the leaves yellow-green or glaucous.

They are chiefly early or mid-season forms, with lax quadrate ears and characteristic swollen spikelets.

The ears are stiff, 9-12 cm. long; the awns of the bearded forms stout, brittle, and scabrid; spikelets 16-20, elongated, often irregularly arranged on the rachis; the grain large and generally soft (Figs. 174, 179).

GROUP III.—Early or mid-season forms, which show affinities with bearded *T. Spelta* ; they are endemic in Persia, Bokhara, and Turkestan, and I have met with examples among wheats from Portugal, Spain, and Argentina (2, Fig. 173).

The young shoots are erect, the straw stiff, of medium height, leaves glaucous or yellow-green.

The ears are 9-12 cm. long, narrow, quadrate, 8-10 mm. across the face and side, lax, with narrow elongated spikelets, the empty glumes rigid and frequently keeled to the base, lateral nerve prominent.

The awns of the flowering glumes 6-10 mm. long, scabrid.

The grain is long, narrow, semi-flinty, and firmly invested by the glumes.

The rachis breaks readily, but is not so brittle as in the typical bearded forms of *T. Spelta*.

GROUP IV. Endemic Japanese and Chinese Wheats.—Very early wheats, which come into ear at Reading about the end of May or first week of June. The young shoots are erect; the straw somewhat short, 95-115 cm. (38-46 inches) high, soft, hollow, and of large diameter; the leaves in some forms yellow-green, in others more or less glaucous. The ears are of medium length (9-12 cm. long), well filled from the base to the apex, the spikelets 22-26, 5- to 7-flowered, frequently ripening 4 grains in each : in several forms some of the ears of a plant are clubbed while the rest are uniformly dense throughout (Fig. 189). The empty glumes are frequently keeled to the base, the awns of the flowering glumes of bearded forms slender and comparatively short (4-6 cm. long). The glumes are thin and very easily separated from the rachis, and the grain often visible between them and readily shed.

The grains are dark red, of fair milling quality.

Although the number in each ear is large, the spikelets even at the base and apex being usually fertile, the total yield in weight is low as the individual grains are small.

Group V.—In this group is included a large series of Spring wheats, bearded forms of which are most prevalent. They are very extensively cultivated in Spain, Portugal, Italy, the United States, Canada, and Argentina, and are early forms, coming into ear at the end of May or first ten days of June at Reading.

The young shoots are erect or semi-erect, and the straw usually of medium height; in some forms the leaves are yellowish-green, in others glaucous.

The ears are lax and compressed, the face considerably wider than the 2-rowed side, the usual density 17-21, spikelets 2- to 3-grained, glumes somewhat thin, the grain often visible between the glumes, generally flinty and of good milling quality.

Group VI.—The wheats of this group are winter forms, late, coming into ear at Reading during the second or third week in June. The young shoots are prostrate, the young leaves narrow, and in many Russian forms strikingly pubescent, the straw somewhat tall and slender. The ears are similar to those of the previous group, lax and compressed, 9-13 cm. long, usual density 17-21, but some forms have a density of 23-27; the spikelets are broad, 2- to 3-grained, with thin glumes, which frequently do not cover the grain.

The grain is generally flinty and of good milling quality.

The bearded forms of these wheats are very widely distributed in Eastern Europe, and are grown also in the United States and Canada, and occasionally in Holland and France and other countries of Western Europe.

Group VII. The Squarehead Group (see p. 296).—In this are included a number of Winter wheats grown chiefly in Western Europe, where intensive cultivation is practised, and there is need of the highest yields per acre in order to secure a remunerative return from the land.

The young shoots are prostrate or semi-prostrate, the straw short and stiff, ears dense, of the Squarehead type (2, Fig. 189; 1, 2, Fig. 190).

They have a long growing period and are very prolific. The grain is usually soft and mealy and the flour of moderate baking quality.

The majority are beardless forms.

1 2

FIG. 170.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *erythrospermum*. (Rieti.)

2. var. *erythrospermum*. (Preston.)

VARIETIES OF *T. vulgare*

I. *Ears bearded*—

1. Glumes white, glabrous.
   - *a*. Grain white . . . . . . var. *graecum*, Körn
   - *b*. Grain red.
     - i. Awns white . . . . var. *erythrospermum*, Körn.
     - ii. Awns black . . . . var. *nigroaristatum*, Flaksb.
2. Glumes white, pubescent.
   - *a*. Grain white.
     - i. Awns white . . . . . var. *meridionale*, Körn.
     - ii. Awns black . . . . var. *pseudomeridionale*, Flaksb.
   - *b*. Grain red.
     - i. Awns white . . . . . var. *Hostianum*, Körn.
     - ii. Awns black . . . . var. *pseudo-Hostianum*, Flaksb.
3. Glumes red, glabrous.
   - *a*. Grain white . . . . . . var. *erythroleucon*, Körn.
   - *b*. Grain red.
     - i. Awns red . . . . . . var. *ferrugineum*, Körn.
     - ii. Awns black . . . . . var. *Sardoum*, Körn.
4. Glumes red, pubescent.
   - *a*. Grain white . . . . . . var. *turcicum*, Körn.
   - *b*. Grain red . . . . var. *barbarossa*, Körn.
5. Glumes grey-blue, glabrous.
   - *b*. Grain red . . . . var. *caesium*, Körn.
6. Glumes blue, pubescent.
   - *b*. Grain red . . . . . . var. *coeruleovelutinum*, Körn.
7. Glumes black, pubescent.
   - *b*. Grain red . . . . var. *fuliginosum*, Körn.

II. *Ears beardless*—

8. Glumes white, glabrous.
   - *a*. Grain white . . . . . . var. *albidum*, Körn.
   - *b*. Grain red . . . . var. *lutescens*, Körn.
9. Glumes white, pubescent.
   - *a*. Grain white . . . . . var. *leucospermum*, Körn.
   - *b*. Grain red . . . . var. *velutinum*, Körn.
10. Glumes red, glabrous.
    - *a*. Grain white . . . . . . var. *alborubrum*, Körn.
    - *b*. Grain red . . . . var. *milturum*, Körn.
11. Glumes red, pubescent.
    - *a*. Grain white . . . . var. *Delfii*, Körn.
    - *b*. Grain red . . . . var. *pyrothrix*, Körn.
12. Glumes blackish-yellow, glabrous . . . var. *triste*, Flaksb.
13. Glumes bluish, pubescent.
    - *b*. Grain red . . . . var. *cyanothrix*, Körn.
14. Glumes black, pubescent . . . . . var. *nigrum*, Körn.

Bearded Varieties

Of some 1300 examples of *T. vulgare* collected from all parts of the world about one-half are bearded.

Among them Spring and Winter wheats are found in almost equal proportion, some of the former being exceptionally rapid in their growth.

In all countries with hot summers, except Australia, bearded varieties prevail, and although the baking quality of the flour of these wheats is usually good, the yield per acre is generally very low.

In Western Europe, where intensive cultivation is practised, such wheats are rarely grown. Occasionally bearded spring forms are sown when adverse climatic conditions have prevented the sowing of the higher-yielding, beardless, Winter wheats, but even in these circumstances a better financial return is generally obtainable from oats, so that on most farms the latter crop, or barley where the soil is suitable, takes the place of wheat when sowing is necessarily delayed until March or April.

There is much less diversity of morphological and physiological characters among the bearded than among the beardless forms of *T. vulgare*. More than 90 per cent possess lax, compressed ears, the density of which average 18-20 and rarely exceed 23-25. The awns are usually divergent, short in comparison with those of *T. durum* or *T. turgidum*, varying in length from 5-10 cm. The empty glumes have fine awns, 1-4 cm. long, or acute, apical teeth, which are never so blunt as those of many beardless varieties and rarely so stout as those of *T. durum* (cf. Figs. 138, 165, 166).

The varieties including the greatest number of forms are *erythrospermum* and *ferrugineum*.

Ear bearded ; glumes white, glabrous ; grain white.

T. vulgare, var. **graecum,** Körn. *Syst. Uebers.* 11 (1873).

Körnicke received his type from Greece ; he obtained examples also from Central Asia, Persia, and India.

The variety is described by Metzger (*Eur. Cer.* p. 1 A), who refers to it as an uncommon wheat found among other varieties in Germany, France, Spain, Italy, and England.

Although one of the less commonly grown varieties of *T. vulgare*, it is widely distributed, especially in the warm wheat-growing regions of Asia.

Of fifty examples collected from different parts of the world, the majority came from Persia, India, and Central Asia (Bokhara and the province of Semiretchensk, Turkestan), single forms only being obtained from Bulgaria, Austria, France, Spain, Egypt, the Transvaal, New Zealand, United States, and Canada.

1. An early form received from the United Provinces, the Punjab, and Bombay, and from Egypt under the name **Hindi.**

Young shoots, erect.

Straw, short and slender, 80-102 cm. (32-40 inches) high ; leaves more or less glaucous.

Ear, 7-9 cm. long, almost square in section, 10 mm. across the face and side, with stout awns 4-6 cm. long ; spikelets 16 to 19, usually overlapping, some-

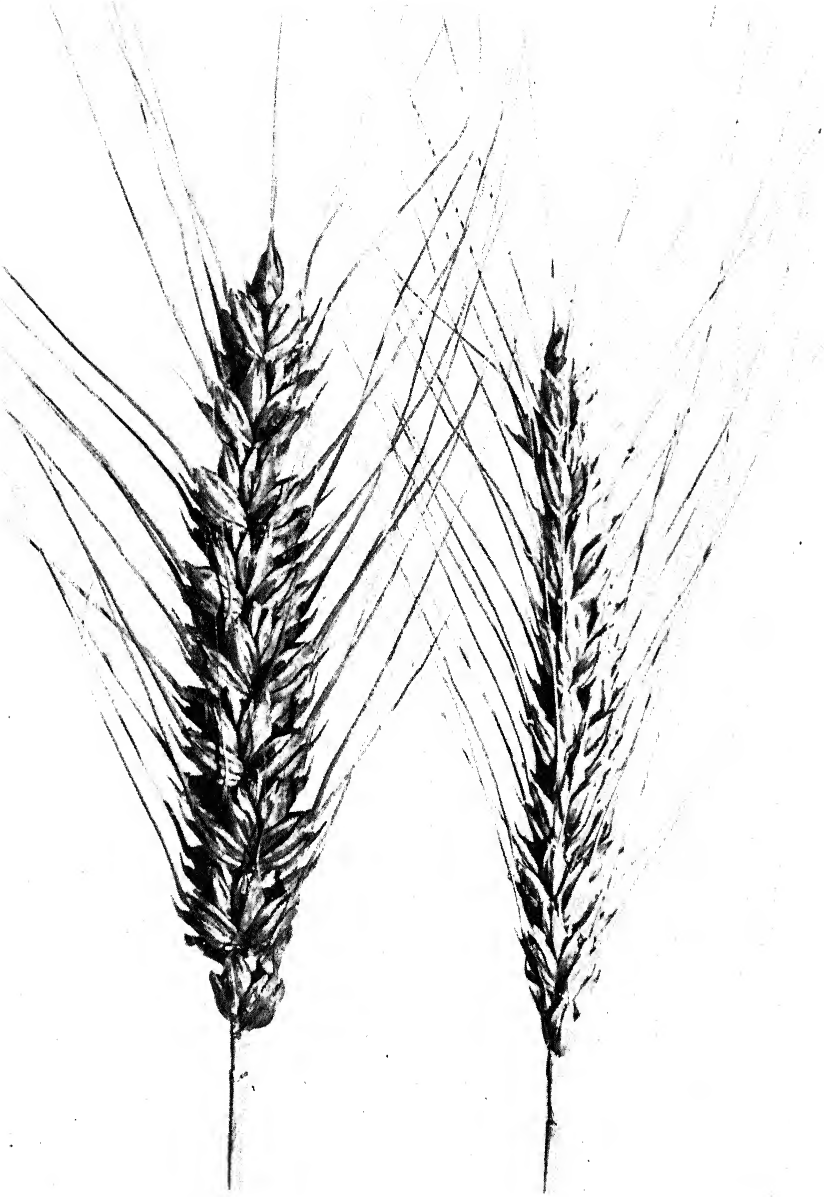


FIG. 171.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *ferrugineum*. (Rouge prolifique.)

2. var. *erythrospermum*. (Roumania.)

times irregularly arranged on the rachis, 3-grained; D=21-25 (Ear type 1, Fig. 176).

Empty glume, 10 mm. long; apical tooth 2-3 mm. long (9, 14, Fig. 165).

Grain, short, mealy, or semi-flinty, 6·1-6·5 mm. long, 3·2-3·5 mm. broad, 3·2-3·4 mm. thick.

Roermaker and **Ecksteen**, with softer glumes, and pale yellowish-green leaves, obtained from the Transvaal, are allied forms, probably derived originally from India.

It is almost impossible to grow any of these wheats in England on account of their susceptibility to attacks of Yellow Rust (*Puccinia glumarum*).

2. An early form received from Ispahan, Persia.

Young shoots, erect.

Straw, of medium height, 100 cm. (about 40 inches) high; leaves glaucous.

Ear, lax, 9-10 cm. long, somewhat quadrate, 10 mm. across the face and side, with plump spikelets and short, stiff awns 3-6 cm. long; spikelets 15-18, plump, 2- to 3-grained; D=16-19 (Ear type 2, Fig. 174).

Empty glume, 9 mm. long, keeled to the base, lateral nerves distinct, apex broad; apical tooth short, curved, 1-2 mm. long.

Grain, large, semi-flinty, plump; 7·4 mm. long, 3·55 mm. broad, 3·35 mm. thick.

3. **Trigo Candeal.**—A mid-season spelt-like form obtained from several districts in Spain and from Italy.

Young shoots, erect.

Straw, tall, 120 cm. (about 48 inches) high; upper internode with thick, pithy walls or solid; leaves glaucous.

Ear, lax, rigid, 10-12 cm. long, somewhat quadrate, 2-11 mm. across the face and side; awns slender, 6-9 cm. long; spikelets 18-22, 3-grained; D=17-21 (Ear type 2, Fig. 173, lax).

Empty glume, 9 mm. long, keeled to the base; apex broad, lateral nerve prominent; apical tooth acute, 3-5 mm. long (6, 20, Fig. 165).

Grain, large, semi-flinty, 7·3-8 mm. long, 3·7-4 mm. broad, 3·4 mm. thick.

4. **Agh Bogda** (White Wheat).—A mid-season spelt-like form received from Tabriz, Persia.

Young shoots, erect or semi-erect.

Straw, of medium height, 90-110 cm. (36-44 inches) high; leaves glaucous.

Ear, lax, 9-11·5 cm. long, flattish, 13 mm. across the face, 8 mm. across the two-rowed side, with somewhat slender awns 6-9 cm. long; spikelets 18-22, 3-grained; D=18-21 (Ear type 1, Fig. 171).

Empty glume, 8-9 mm. long, keeled to the base, apex broad, apical tooth or awn 2-5 mm. long (6, 8, Fig. 165).

Grain, semi-flinty or mealy, 6·5 mm. long, 3·2-3·7 mm. broad, 3-3·2 mm. thick.

Allied spelt-like forms under the names **Kizil Goon** (golden colour) and **Ablakh** (spotted), with broader glumes and larger grain (7·1 mm. long, 3·85 mm. broad, 3·5 mm. thick), were obtained from Tabriz and also from Turkestan.

5. Winter forms from Russia, Bulgaria, Austria, and France.

Young shoots, prostrate or semi-prostrate.

Straw, tall, 110-120 cm. (44-48 inches) high.

Ear, 10-11 cm. long, awns slender, 6-7 cm. long; spikelets 18-21, 2- to 3-grained; D = 18-21 (Ear type 2, Fig. 170).

Empty glume, 9-10 mm. long, keeled to the base, apex broad; apical tooth acute, 1-3 mm. long (6, 8, Fig. 165).

Grain, flinty or semi-flinty, 6·8-7 mm. long, 3·9 mm. broad, 3·3 mm. thick.

6. **Shirreff's White Bearded.**—A winter form introduced by P. Shirreff about 1860; it is a hardy wheat, productive and late, coming into ear at Reading in the second or third week of June.

Young shoots, prostrate.

Straw, very tall, slender, 130-140 cm. (about 52-56 inches) high.

Ear, 10-12 cm. long, almost square in section, 10-11 mm. across the face and side, with divergent awns 8-10 cm. long; spikelets 22-25, 3-grained; D = 23-26 (Ear type 1, Fig. 178, with awns).

Empty glume, 7 mm. long, apex narrow; apical tooth acute, 2 mm. long.

Grain, semi-flinty, small, plump; 6·2-7 mm. long, 3·7-4 mm. broad, 3·2-3·5 mm. thick (9, Fig. 165).

Ears bearded; glumes white, glaucous; awns white; grain red.

T. vulgare, var. **erythrospermum**, Körn. *Syst. Uebers.* 11 (1873).

This is one of the most widely distributed varieties of *T. vulgare*, forms of it being found in almost all countries where wheat is cultivated. It is grown more especially in regions having cold winters and hot summers.

Of the 250 examples collected from various parts of the world the majority came from Russia, Roumania, Hungary, Spain, India, and the United States, but a few were received also from Asia Minor, Persia, China, Japan, Manchuria, Morocco, South Africa, Argentina, Australia, Portugal, Austria, Germany, Holland, France, and England.

The greatest number are Spring and Winter wheats with lax, compressed ears. With the exception of one or two prolific, bearded, Squarehead wheats they give poor yields of grain, although the baking quality of their flour is generally excellent.

1. An early form received from the Punjab, India, and common among commercial samples from Karachi and Calcutta; in ear at Reading about the end of May.

Young shoots, erect.

Straw, short and slender, 80-96 cm. (32-38 inches) high; leaves yellowish-green.

Ear, 7-8 cm. long, somewhat square in section, with slender, divergent awns 5-6 cm. long; spikelets 17-19, 3-grained; D = 20-23 (Ear type 1, Fig. 176).

Empty glume, 9 mm. long, apex broad; apical tooth 2 mm. long (9, 21, Fig. 165).

Grain, flinty or semi-flinty, 6·5-6·7 mm. long, 3·5 mm. broad, 3·1 mm. thick.

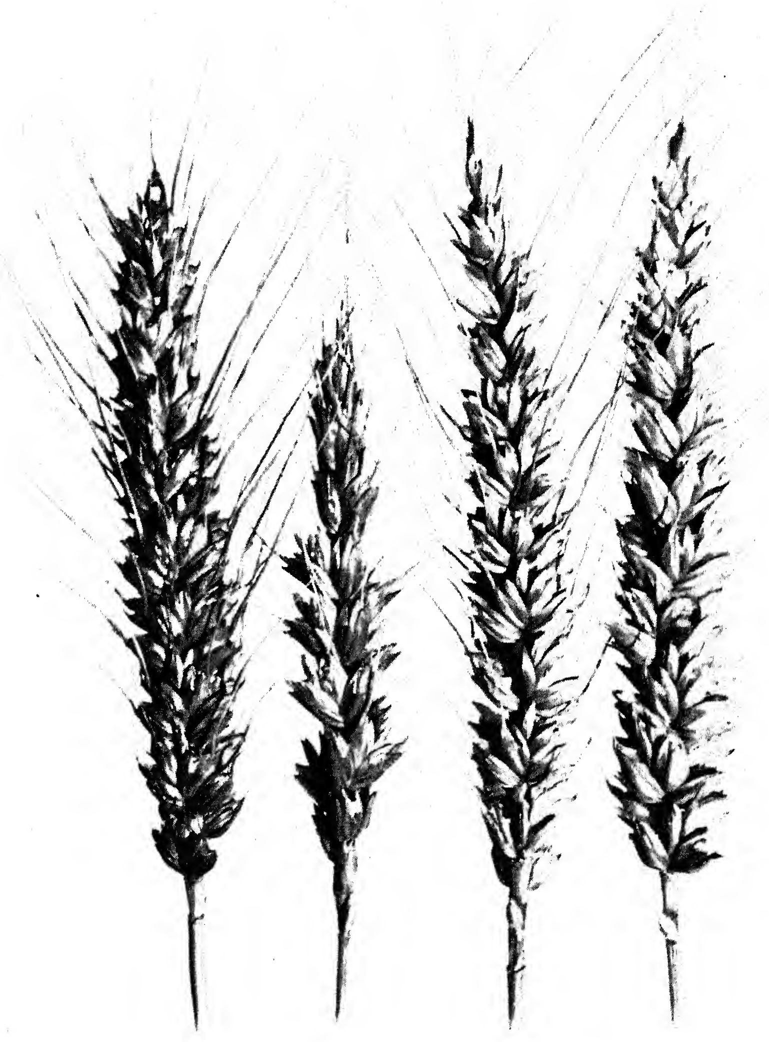


FIG. 172.—BREAD WHEAT (*T. vulgare*, Host).

var. *ferrugineum*.
(Japanese forms.)

2. From the Punjab and the United Provinces was received a common form similar to (1) in most morphological characters, but possessing more erect ears and blue-green foliage.

3. Early forms received from various parts of Persia; some forms of **Chul** belong to these.

Young shoots, erect.

Straw, stout, of medium height, 95-110 cm. (38-44 inches) high.

Ear, lax, 11-13 cm. long, awns 3-5 cm. long; spikelets inflated and elongated, 18-20, 2- to 3-grained; D = 17-20 (Ear types 1, Fig. 173; 1, 2, Fig. 174).

Empty glume, 10 mm. long, broad, keeled to the base; apical tooth acute, 1-3 mm. long (6, 7, 10, Fig. 165).

Grain, large, flinty, or semi-flinty, 8·2 mm. long, 3 mm. broad, 3·4 mm. thick.

4. An early, somewhat spelt-like form, with rough, rigid ears and narrow grains; received from Yezd, Ispahan, Tabriz, and from Bokhara, and Semiretchensk. Similar forms occur among Portuguese, Spanish, and Argentine wheats.

Young shoots, erect.

Straw, tall, 112-125 cm. (about 44-50 inches) high; leaves glaucous.

Ear, narrow, 10-13 cm. long, almost square in section, 8-10 mm. across the face and side, with hard glumes and stiff awns 6-8 cm. long; spikelets 19-22, 2- to 3-grained; D = 16-19 (Ear type 2, Fig. 173).

Empty glume, 10 mm. long, keeled to the base, apex broad; apical tooth 3 mm. long (6, 10, Fig. 165).

Grain, semi-flinty, long, apex narrow, 7·4-8·4 mm. long, 3-3·6 mm. broad, 3-3·6 mm. thick.

5. **Rieti.**—An early form; received from France, Italy, and Spain under various names; it comes into ear at Reading about June 9.

Most forms of Rieti have a pale red chaff.

Young shoots, erect.

Straw, slender, tall, 116 cm. (46 inches) high; leaves yellow-green.

Ear, very lax, 12-13 cm. long; awns 8-9 cm. long, spreading; spikelets 21-22; D = 16-18 (Ear type 1, Fig. 170).

Empty glume, 9 mm. long, apex narrow, its awn 1·5-2 cm. long (2, Fig. 165).

Grain, long, semi-flinty, 7·65 mm. long, 3·6 mm. broad, 3·15 mm. thick.

6. **Soshu Shirokawa.**—A very early form from Japan, having characteristic ears with well-filled spikelets, which shed their glumes and grain very readily.

Young shoots, erect.

Straw, stout, erect, of medium height, 100-110 cm. (about 40-44 inches) high; leaves glaucous.

Ear, 10-11 cm. long with broad, well-filled spikelets, thin glumes often not completely enclosing the grain, and fine, spreading awns 5-6 cm. long; spikelets 20-22, 3- to 4-grained; D = 20-22 (Ear type 1, Fig. 172).

Empty glume, 7-8 mm. long, keeled to the base; apical tooth or awn 2-6 mm. long (5, 17, Fig. 165).

Grain, short, dark red, flinty or semi-flinty, with blunt apex, 6 mm. long, 3·5-3·6 mm. broad, 3·1 mm. thick.

Kintana and other forms resembling (1), but with yellowish-green leaves, were also received from Japan.

Allied to these early Japanese wheats, with non-glaucous, yellow-green leaves and small, dark red, semi-flinty grain, are two forms obtained from Chungking, China:

(*a*) With lax ears, 10-11 cm. long; D = 18-19.

(*b*) With denser, square ears, 9 cm. long; D = 25-27.

7. An early or mid-season form received from Italy and various districts in Spain.

Young shoots, erect.

Straw, fine, tall, about 120 cm. (48 inches) high; leaves glaucous.

Ear, very lax, 11-14 cm. long; awns slender, 6-10 cm. long; spikelets 20-23, large, 3-grained; D = 16-18 (Ear type 1, Fig. 169).

Empty glume, 8-9 mm. long, keeled to the base; apical tooth or awn 4-6 mm. long (14, Fig. 165).

Grain, long, narrow, semi-flinty, 7·1 mm. long, 3·3-3·5 mm. broad, 3 mm. thick.

8. A widely distributed form of Spring wheat, received chiefly from Spain, Italy, Portugal, and Argentina; the grain is of good quality, the ears shorter, squarer, and slightly denser, and spikelets more overlapping than the preceding.

Young shoots, erect.

Straw, tall, 115-140 cm. (about 55 inches) high; young leaves glaucous.

Ear, lax, 9-11 cm. long, somewhat square in section, 9-11 mm. across the face and side; awns divergent, 8-9 cm. long (Ear types 1, 2, Fig. 170); spikelets 18-21, 3-grained; D = 18-21.

Empty glume, 9-10 mm. long, keeled to the base; apical tooth or awn 4-6 mm. long (3, 14, Fig. 165).

Grain, flinty, 7 mm. long, 3·4 mm. broad, 3 mm. thick.

9. A very widely distributed winter form with grain of fine quality; cultivated extensively in European Russia, Austria, Hungary, and Roumania, the United States, and Canada; also received from France and Holland. **Turkey Red**, **Malakov**, **Banat**, and **Lancaster** are examples.

Young shoots, prostrate.

Straw, tall, 120-130 cm. (48-52 inches) high.

Ear, lax, 9-13 cm. long, compressed, 12-14 mm. across the face, 8-10 mm. across the 2-ranked side; awns divergent, 6-8 cm. long; spikelets 23-26 broad, 3-grained; D = 18-22 (Ear types 2, Fig. 170; 2, Fig. 171).

Empty glume, 9-10 mm. long; apical tooth 2-5 mm. long (8, 21, Fig. 165).

Grain, flinty, somewhat short, apex blunt; 6·8-7 mm. long, 3·5 mm. broad, 3 mm. thick.

10. **Badger.**—A prolific Winter wheat selected by the author from an Austrian form.

1 2

FIG. 173.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *graecum*. (Chul.)

2. var. *erythrospermum*. (Persia.)

Allied to it, but with less dense ears, are **Beal** and **Strube's Hybrid** from Germany.

Young shoots, prostrate.

Straw, stiff, of medium height, 96-115 cm. (38-44 inches) high; leaves glaucous.

Ear, dense, 8-9 cm. long, 12-14 mm. across the face, 10 mm. across the 2-ranked side; awns slender, 5-6 cm. long; spikelets 23 to 26, 3-grained; D = 30-32 (Ear type 2, Fig. 176).

Empty glume, 8 mm. long, inflated; apical awn or tooth curved at the base, 2-3 mm. long (15, Fig. 165).

Grain, semi-flinty, plump, 6·9-7 mm. long, 3·9 mm. broad, 3 mm. thick.

Ear bearded; glumes white, glabrous; awns black; grain red.

T. vulgare nigroaristatum, Flaksb. *Bull. App. Bot. Petrograd*, viii. 195 (1915).

According to Flaksberger, this variety occurs sporadically among other wheats in Russia.

Ear bearded; glumes white, pubescent; grain white.

T. vulgare, var. **meridionale,** Körn. *Handb. d. Getr.* i. 47 (1885).

Körnicke's type was obtained from Greece, but the variety is endemic in Asia.

Of the 22 examples grown at Reading, 2 were from India, 1 from Rhodesia, 1 from the Province of Syr Daria, Turkestan, the rest (18) came from Persia (Bushire, Tabriz, Ispahan, Arabistan).

All the forms of this variety are early wheats; those from India with short straw and ears, the Persian forms having straw of medium height and lax ears 9-11 cm. long.

1. A very early form received from Cawnpore.

Young shoots, erect.

Straw, of medium height, 89-102 cm. (35-40 inches) high; leaves blue-green.

Ear, 7-8 cm. long, with rigid, spreading awns 5-6 cm. long; spikelets 15-18 overlapping, often irregularly arranged on the rachis; D = 20-23 (Ear type 1, Fig. 176).

Empty glume, 8 mm. long, keeled to the base, apex broad; apical tooth stout, acute, 2 mm. long.

Grain, small, flinty, 6·25 mm. long, 3·2 mm. broad, 3·1 mm. thick.

Allied forms with yellow-green leaves were obtained from Arabistan and Rhodesia, the latter probably derived originally from India.

2. **Agh Bogda** (White Wheat).—A mid-season form received from Tabriz, Persia.

Young shoots, semi-erect.

Straw, medium to tall, 104 cm. (40-46 inches) high; leaves glaucous.

Ear, lax, 9-11 cm. long, somewhat square in section; with stout awns 7-9 cm. long; spikelets 17-19, inflated, often 4-grained; D = 16-20 (Ear type 1, Fig. 179, with awns).

Empty glume, 10 mm. long, keeled to the base ; apical awn acute, 10-20 mm. long, with a narrow, dark brownish-purple line along the inner margin (3, 6, Fig. 165).

Grain, large, more or less mealy, plump ; 7·5-7·8 mm. long, 3·8 mm. broad, 3·45 mm. thick.

Similar forms are **Sari Bogda** (yellow wheat), **Kizil Goon** (golden colour), and **Ablakh** (spotted), from the same district ; others also from Ispahan, Persia, and one from Syr Daria, Turkestan.

Ear bearded ; glumes white, pubescent ; awns black ; grain white.

T. vulgare, var. **pseudo-meridionale**, Flaksb. *Bull. App. Bot. Petrograd*, viii. 163 (1915).

A very rare variety, hitherto found only in Asia.

Flaksberger states that this variety frequently occurs among other wheats in Persia and Turkestan.

Howard's var. *meridionale*, United Provinces Class 6, appears to belong to this also (*Wheat in India*, p. 193).

Ear bearded ; glumes white, pubescent ; awns white ; grain red.

T. vulgare, var. **Hostianum**, Körn. *Handb. d. Getr.* i. 47 (1885).

A rare variety known to Körnicke only from Botanic Gardens. It occurs among commercial White Karachi wheat from India, and I have received ten or twelve forms of it from the United Provinces, India, Tabriz, and Seistan in Persia, the province of Semiretchensk, Turkestan, and a single form from Professor Eriksson, Stockholm.

1. An early form found in commercial white Karachi wheat and received also from Cawnpore, India. At Reading it comes into ear about the end of May or first week of June.

Young shoots, erect or semi-erect.

Straw, short, slender, erect, 76 cm. (30 inches) high ; leaves blue-green.

Ear, dense, 7·5-8 cm. long, quadrate, 10-11 mm. across the face and side, with somewhat slender awns 6-7·5 cm. long ; spikelets 16-19 ; D = 24-28 (Ear type 1, Fig. 176).

Empty glume, 9 mm. long, keeled to the base, with apical tooth or awn 4-10 mm. long (15, 16, Fig. 166).

Grain, flinty, dark red, small, plump ; apex blunt, 6·2-6·8 mm. long, 3·6-4 mm. broad, 3-3·25 mm. thick.

2. **Ablakh** (Spotted).—An early wheat received from Tabriz, Persia.

Young shoots, erect or semi-erect.

Straw, stout, of medium height 100-110 cm. (40-44 inches) high ; leaves blue-green.

Ear, lax, 10-11 cm. long, with stout awns, 7-8 cm. long ; spikelets 15-16, plump, inflated, 3- to 4-grained ; D = 16-19 (Ear type 2, Fig. 187, with awns).

Empty glume, 10 mm. long, keeled to the base ; apical tooth 2-4 mm. long, with a narrow, dark brownish-purple line along the inner margin.

Fig. 174.—Bread Wheat (*T. vulgare*, Host).

1. var. *pseudoturcicum*. (Kadiz Oglau.)

2. var. *erythroleucon*. (Kalkori.)

Grain, large, dark red, flinty, 7·5 mm. long, 3·5-4 mm. broad, 3·5 mm. thick.

A similar form with more hairy leaves from Seistan, Persia, under the name **Nishkin.**

3. An early form received from the province of Semiretchensk, Turkestan.

Young shoots, erect.

Straw, of medium height, 100-110 cm. (40-44 inches) high.

Ear, 8-10 cm. long, with spreading awns 5-6·5 cm. long; spikelets 17-19; D=20-25 (Ear type 2, Fig. 170).

Empty glume, 8 mm. long, keeled to the base; apical tooth 2 mm. long, lateral nerve distinct; no dark margin to the glume (8, 14, Fig. 165).

Grain, dark red, 6·5 mm. long, 3·4 mm. broad, 3·3 mm. thick.

4. A very late winter form, received from Prof. Eriksson, Stockholm; it comes into ear at Reading about the third week in June.

Young shoots, prostrate.

Straw, slender, erect, of medium height, 109 cm. (43 inches); leaves blue-green.

Ear, 9-10.5 cm. long with slender, spreading, somewhat wavy awns 5-6 cm. long; spikelets 22, short, 3-grained; D=22-24 (Ear type 2, Fig. 177, with awns).

Empty glume, 7 mm. long, keeled to the base; apical tooth slender, 2-3·5 mm. long (Form 21, Fig. 165).

Grain, more or less visible between the glumes, semi-flinty, 6·45-6·6 mm. long, 3·45-4 mm. broad, 3·4 mm. thick.

Ear bearded; glumes white, pubescent; awns black; grain red.

T. vulgare, var. **pseudo-Hostianum**, Flaksb. *Bull. App. Bot. Petrograd*, viii. 165, 196 (1915).

A very rare variety occurring only in Central Asia.

Flaksberger states that examples are occasionally found in Turkestan and Persia, mixed with other wheats.

I obtained examples among Ablakh wheat from Tabriz, Persia, exactly similar to the Ablakh form described under var. *Hostianum* (p. 280), but with black awns.

Punjab 9.—Received from India. A distinct form with dense, square ears and villose glumes, the hairs conspicuous and spreading.

Straw, tall, hollow, 118-120 cm. (46-47 inches) high.

Ear, 6·5-7·5 cm. long, dense, square, 10-11 mm. across the sides; spikelets 18-20; D=30 (Ear types 2, Fig. 175; 2, Fig. 176 but narrower); awns rigid, stout, and short, 5·5-6·5 cm. long.

Empty glume, 8-9 mm. long, with prominent apex and awn 5-6 mm. long (Form 20, Fig. 165).

Grain, dark red, flinty, 6·8 mm. long, 3·4 mm. broad, 3·1 mm. thick.

Ear bearded; glumes red, glabrous; grain white.

T. vulgare, var. **erythroleucon**, Körn. *Handb. d. Getr.* i. 47 (1885).

A rare variety endemic in Central Asia, Persia, and India.

Körnicke's examples were derived from Turkestan, Persia, and India. Of the 22 examples grown at Reading 12 were obtained from India (the Punjab and United Provinces), 3 from Persia, 3 from Syr Daria and Semiretchensk, Turkestan, 2 from the Transvaal, and 1 each from France and Spain.

1. An early form received from the Punjab and the United Provinces. Several closely similar forms with bluish-green leaves and semi-flinty grain were received from Karachi, Cawnpore, and Calcutta.

Young shoots, erect.

Straw, short, slender, 90-125 cm. (36-45 inches) high ; leaves pale-yellowish green.

Ear, lax, 6·5-8·5 cm. long ; awns short, spreading, 6-7 cm. long ; spikelets 16, irregularly arranged on the rachis and usually overlapping each other in the denser ears ; D = 18-23 (Ear types 2, Fig. 173 ; 1, Fig. 176).

Empty glume, rigid, 10 mm. long, keeled to the base ; apical tooth acute, 2-3 mm. long (8, 14, Fig. 165).

Grain, flinty, dorsal ridge prominent, apex truncate, 7·2 mm. long, 3·9 mm. broad, 3·5 mm. thick.

An allied form with yellow-green leaves and one under the name **Siebritz** with somewhat glaucous foliage were received from the Transvaal.

2. An early form received from Tabriz, Persia, Syr Daria, and Semiretchensk, Turkestan.

Young shoots, erect.

Straw, of medium height, 100-110 cm. (40-44 inches) high ; leaves blue-green.

Ear, glaucous, 8-12 cm. long, narrow, quadrate, 9-10 mm. across the face and side, with slender awns 6-8 cm. long ; spikelets 16-18, 2-grained ; D = 17-21 (Ear type 2, Fig. 173).

Empty glume, 9 mm. long, keeled to the base ; apical tooth or awn 3 mm. long (2, 6, Fig. 165).

Grain, flinty, long, and somewhat narrow, 8 mm. long, 3·6 mm. broad, 3·1 mm. thick.

3. **Perle de Nuisement.**—A very late winter form received from France ; it comes into ear June 16-28 at Reading.

Young shoots, prostrate.

Straw, slender, tall, 127 cm. (50 inches) high ; leaves yellow-green.

Ear, 9-12 cm. long, with broad, well-filled spikelets and spreading awns 8-9 cm. long ; spikelets 20-24, often 4-grained ; D = 20-22 (Ear type 1, Fig. 171).

Empty glume, 9-10 mm. long, keeled to the base, apex narrow ; apical tooth acute, 3 mm. long (15, Fig. 165).

Grain, flinty, 6·5 mm. long, 3·5-3·7 mm. broad, 3·25 mm. thick.

A closely similar form with blue-green leaves was received from Spain under the name **Del Frailte**.

Ear bearded ; glumes red, glabrous ; awns red ; grain red.

T. vulgare, var. **ferrugineum**, Körn. *Handb. d. Getr.* i. 47 (1885).

Like the corresponding white-chaffed var. *erythrospermum* this is widely

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FIG. 175.—BREAD WHEAT (*T. vulgare*, Host).

var. *ferrugineum*.
(Siberian forms.)

distributed and includes a large number of forms, most of which are Spring and Winter wheats with lax, compressed ears, and grain of high quality. Over 200 examples of it have been collected and grown at Reading, these coming from every country where wheat is cultivated.

As in the case of the corresponding white-chaffed var. *erythrospermum*, the commonest forms possess lax, compressed ears; dense-eared forms are exceptionally rare in this variety.

1. Very early forms from Northern India and Persia; they come into ear at Reading about the end of May.

Young shoots, erect.

Straw, short, slender, 70-85 cm. (28-34 inches) high; leaves yellow-green.

Ear, 7·5-9·5 long, almost square in section, 10-12 mm. across the face; awns 4-7 cm. long, stout at the base, brittle; spikelets 16, elongated; D = 16-20 (Ear type 1, Fig. 176).

Empty glume, rigid, 9-10 mm. long, keeled to near the base; apical tooth 2-3 mm. long (14, 20, 21, Fig. 165).

Grain, flinty, well-filled, 7·5-7·9 mm. long, 3·7 mm. broad, 3·5 mm. thick.

2. Forms similar to the preceding, with ears 9-11 cm. long, spikelets overlapping, and density 20-25, are frequent in Persia, Central Asia, and India; **van Niekirk's** wheat received from the Transvaal belongs to these.

3. Spelt-like early forms from Bokhara, Turkestan, and other parts of Central Asia.

Young shoots, erect.

Straw, stout, rigid, of medium height, 100 cm. (about 40 inches) high; leaves yellow-green.

Ear, long, lax, 10-12 cm. long, somewhat square, 10 mm. across the face and side; awns rigid, 6-8 cm. long; spikelets 16-18, narrow, elongated, 2- to 3-grained; D = 16-20 (Ear types 1, 2, Fig. 173).

Empty glume, rigid, 10 mm. long, keeled to the base, apex usually broad with prominent lateral nerve; apical tooth acute (4, 6, Fig. 165).

Grain, flinty or semi-flinty, 6·8-7 mm. long, 3·6 mm. broad, 3 mm. thick.

4. **Barletta.**—An early form received from Spain, Argentina, and Paraguay; it comes into ear at Reading about the first week in June.

Young shoots, erect.

Straw, tall, 118-132 cm. (47-52 inches) high; leaves glaucous.

Ear, long, lax, 10-12 cm. long, almost square in section, 10-12 mm. across the face and side; awns 8-9 cm. long; spikelets 18-21, elongated; D = 19 (Ear type 2, Fig. 173).

Empty glume, pale red, 8-10 mm. long, rigid, keeled to the base; apical tooth or awns 2-5 mm. long; lateral nerve prominent (14, 15, Fig. 165).

Grain, semi-flinty, apex narrow, 6-7 mm. long, 3-5 mm. broad, 3·2 mm. thick.

5. Somewhat similar are several forms received from Spain with more rigid ears and glumes, and longer, flinty grain, 8 mm. long, 3·5 mm. broad, 3·25 mm. thick.

6. **Aka Yenidashi.**—An early form received from Japan ; it comes into ear at Reading about the end of May.

Young shoots, erect.

Straw, of medium height, about 96 cm. (38 inches) high ; leaves yellow-green.

Ear, lax, 8-9 cm. long ; awns 5-6 cm. long, spreading ; spikelets broad, 16-20 ; D = 20-23 (Ear types 3, 4, Fig. 172).

Empty glume, 8 mm. long, keeled to the base, apex broad ; apical tooth acute, 3 mm. long (5, 6, 19, Fig. 165).

Grain, flinty, 6 mm. long, 3·1 mm. broad, 2·6 mm. thick.

Allied to this is **Hosagara**, also from Japan, with less erect young shoots, slightly taller straw, and plumper, broader grain.

7. **Daruma.**—An early form received from Japan ; it comes into ear at Reading about the end of May.

Young shoots, semi-erect.

Straw, stout, medium to tall, 100-115 cm. (40-46 inches) high ; leaves yellow-green.

Ears, 10 cm. long ; awns 5-6 cm. long, stout, spreading ; spikelets 25 ; D = 25 (Ear type 1, Fig. 172).

Empty glume, short, inflated, 7 mm. long, apex broad ; apical tooth bent inwards, 4 mm. long (19, Fig. 165).

Grain, flinty, short, plump, 5·2 mm. long, 3·3 mm. broad, 3·1 mm. thick.

Resembling this is a denser-eared Japanese form (D = 27-31), **Sunagawa yanagi Kobu**, with shorter, more slender awns, and somewhat longer grain.

8. **Hsu Hsu Mai.**—An early form received from Chungking, China ; it has given rise to several semi-bearded forms, with short awns 1·5-2 cm. long.

Young shoots, erect.

Straw, short to medium height, 85-90 cm. (about 36 inches) high ; leaves yellow-green.

Ear, lax, 10-11 cm. long, with very fine awns 7-8 cm. long ; spikelets broad, 21 ; D = 20-23 (Ear type 1, Fig. 172).

Empty glume, 8 mm. long, apex broad, lateral nerve distinct ; apical tooth acute, 3 mm. long, curved inwards slightly (19, Fig. 165).

Grain, mealy, apex narrow, dorsal ridge somewhat prominent, 6·3 mm. long, 3·45 mm. broad, 3·15 mm. thick.

9. **Xeixa.**—A late form received from Spain ; it comes into ear at Reading about June 18.

Young shoots, erect.

Straw, slender, tall, about 127 cm. (50 inches) long ; leaves yellow-green.

Ears, lax, 10-12 cm. long, with awns 8 cm. long, 12-14 mm. across the face, 10 mm. across the side ; spikelets 16-18 ; D = 18 (Ear type 1, Fig. 170).

Empty glume, 8 mm. long ; apical tooth or awn 2-15 mm. long (8, 15, Fig. 165).

Grain, flinty, apex somewhat truncate, 7·1 mm. long, 3·65 mm. broad, 3·35 mm. thick.

Romanella from Italy and many forms received from Spain under different names resemble this.

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FIG. 176.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *erythrospermum*.

2. var. *erythrospermum*. (Bearded Squarehead.)

10. **La Pera.**—An early form received from Spain; it comes into ear at Reading about the first week in June.

Young shoots, erect.

Straw, slender, tall, 110-120 cm. (44-48 inches) high; leaves glaucous.

Ear, lax and flattish, 10-12 cm. long, 12 mm. across the face, 9-10 mm. across the side; awns 8-9 cm. long; spikelets 18-20; D = 18 (Ear types 1, 2, Fig. 170).

Empty glume, pale red, 10 mm. long, 3·55 mm. broad, 3·35 mm. thick (2, 8, Fig. 165).

Grain, long, flinty, 7-8 mm. long, 3·55 mm. broad, 3·35 mm. thick.

11. Winter (Azima) wheats received chiefly from Russia, Roumania, and Bulgaria; the commonest forms of var. *ferrugineum*.

Young shoots, prostrate.

Straw, tall, slender, 110 cm. (44 inches) high; leaves glaucous.

Ear, lax, 10-13 cm. long, often tapering towards both ends; spikelets 22-24; D = 19-20 (Ear types 1, Fig. 170; 2, Fig. 171).

Empty glume, 10 mm. long, keeled to near the base, apex bluntish; apical tooth acute, 2-4 mm. long (2, 20, Fig. 165).

Grain, flinty or semi-flinty, 6·8 mm. long, 3·65 mm. broad, 3·1 mm. thick.

12. Fine, narrow-eared forms, with very small, narrow, pointed grains; var. *ferrugineum sibiricum* of Flaksberger. Early to mid-season wheats received from Russia in commercial samples of Ulka and "Fine North Russian Wheat," and from Canada under the name **Onega.**

Young shoots, semi-erect.

Straw, slender, of medium height, 100-110 cm. (40-44 inches) high; leaves glaucous and usually pubescent.

Ear, narrow, tapering, 6-10 cm. long, with fine awns 5 cm. long; spikelets 23-27; D = 22-25 (Ear types 1, 2, Fig. 175).

Empty glume, narrow, keeled to the base, 8-9 mm. long, apex truncate; apical tooth 1-1·5 mm. long, acute (13, Fig. 165).

Grain, flinty, narrow, very small, 5·9-6·3 mm. long, 2·65-2·9 mm. broad, 2·3-2·9 mm. thick.

Allied to these forms are **Rouge barbu de Mars** from France.

13. **Carman.**—A dense-eared late form received from Haage and Schmidt, Germany.

Young shoots, prostrate.

Straw, of medium height, about 100 cm. (40 inches) high; leaves glaucous.

Ear, dense, 9-10 cm. long, square, 10-11 mm. across the face and side; awns fine, 4-6 cm. long; spikelets 22-25; D = 25-30.

Empty glume, 9-10 mm. long, keeled to the base, apex broad; apical tooth stout, short.

Grain, plump, mealy, 7·2 mm. long, 4 mm. broad, 3·3 mm. thick.

Somewhat similar to this are **Michigan Bronze** and **Golden Cross.**

Early bearded ; glumes red, glabrous, awns black ; grain red.

T. vulgare, var. **Sardoum**, Körn. *Handb. d. Getr.* i. 46 (1885).

The varietal name was given by Körnicke to a wheat mentioned by Seringe (*Cér. eur.* p. 127) as "variation F. Touzelle Saisette (brune chauvre, barbes noires) or Touzelle de Sardaigne," a bearded form with lax, yellowish-red ears, awns almost black, stiff straw, and soft grain tending to become hard ; the colour of the grain is not given by Seringe.

I have seen no variety of *T. vulgare* with all the characters mentioned by Körnicke.

Ear bearded ; glumes red, pubescent ; grain white.

T. vulgare, var. **turcicum**, Körn. *Handb. d. Getr.* i. 48 (1885).

A rare variety, which I have received only from Asia, 1 example from India, 1 from Turkestan, and 11 from Persia.

Körnicke's examples came from Kastamoni, near the north coast of Asia Minor, and from Turkestan, Central Asia.

1. An early form received from Cawnpore, India.

Young shoots, semi-erect.

Straw, slender, of medium height, 90-110 cm. (36-44 inches) high ; leaves pale yellowish-green.

Ear, short, somewhat dense, 7 cm. long, with spreading awns 5-6 cm. long ; spikelets 16-18 ; D = 23-28 (Ear type 2, Fig. 170).

Empty glume, 8-9 mm. long, keeled to the base ; apical tooth *durum*-like, stout, acute, 1-2 mm. long (16, 18, Fig. 165).

Grain, small, flinty, 6 mm. long, 2·7 mm. broad, 2·8 mm. thick.

2. **Kar-i-safid**—A very distinct early form received from Khorasan, Persia, where it is grown on irrigated soils.

Young shoots, erect.

Straw, of medium height, 110 cm. (about 44 inches) high ; leaves blue-green.

Ear, lax, 10-13 cm. long, with inflated spikelets arranged irregularly on the rachis, and spreading awns 9-10 cm. long ; spikelets 20-21, 3- to 4-grained ; D = 18-20 (Ear type 1, Fig. 179, with awns).

Empty glume, 10 mm. long, inflated ; apical tooth narrow, 4-10 mm. long (14, 20, Fig. 165).

Grain, large, mealy, or semi-flinty, 7·2-7·4 mm. long, 3·8 mm. broad, 3-4 mm. thick.

Allied to it are forms from Ispahan, Persia, and Turkestan, and a true Winter wheat with prostrate young shoots from Tabriz under the name **Kizil Goon** (golden colour), with amber, flinty grain.

Ear bearded ; glumes red, pubescent ; grain red.

T. vulgare, var. **barbarossa**, Körn. *Handb. d. Getr.* i. 48 (1885).

A rare variety, endemic only in Persia and India.

Körnicke received examples from Kastamoni, near the north coast of Asia Minor, Turkestan, and North America.

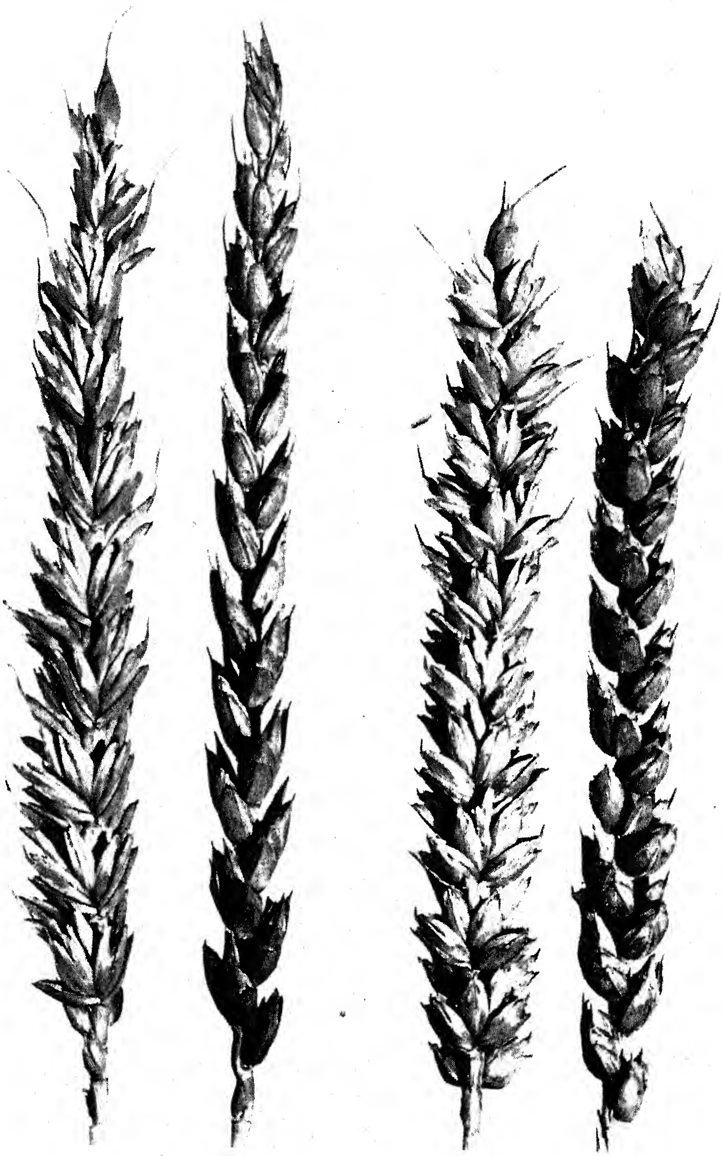

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Fig. 177.—Bread Wheat (*T. vulgare*, Host).

1. var. *lutescens*. (Granella di Carpegna.)

2. var. *albidum*. (Bordier.)

Three examples were sent to me from India (the Punjab and United Provinces), 2 from Eastern Bokhara, 9 from various provinces of Persia, and an isolated form from Rhodesia, South Africa.

An early form received from Karachi; similar forms also from Cawnpore and the Punjab, India.

Young shoots, semi-erect.

Straw, of medium height, 106 cm. (42 inches high); leaves pale yellowish-green.

Ear, 10-11 cm. long, with spreading, somewhat slender awns 5-7 cm. long; spikelets 19-21, large, well-filled, 3- to 4-grained; D = 18-21 (Ear types 2, Fig. 170; 1, Fig. 176).

Empty glume, 9-10 mm. long, with acute, apical awn, 4-6 mm. long (14, 20, Fig. 165).

Grain, semi-flinty, narrowed at the apex, 6·5-6·9 mm. long, 3·4 mm. broad, 3·3 mm. thick.

A series of forms similar in all respects to Kar-i-safid wheat (var. *turcicum*), but with red grains, were received from Tabriz under the name **Sari Bogda** (yellow wheat), Ispahan and Seistan in Persia, and from E. Bokhara; a single example also from Rhodesia.

Ear bearded; glumes grey-blue, glabrous; grain red.

T. vulgare, var. **caesium**, Körn. *Handb. d. Getr.* i. 47 (1885).

A very rare variety, a specimen of which Körnicke obtained from Botanic Gardens.

Metzger (*Eur. Cer.* p. 4, F.) describes a lax-eared form of this variety with the following characters:

Straw, tall, 116-132 cm. (46-52 inches) high, hollow.

Ear, 8-11 cm. long, erect, flattish, tapered towards the apex.

Empty glume, pointed, with long, apical tooth; upper portion of flowering glume bluish, the base white; awns spreading, rough, brownish, as long as, or longer than, the ear.

Grain, mealy, oval, short, reddish-grey.

A Spring wheat, giving only a moderate yield.

Ear bearded; glumes grey-blue, pubescent; grain red.

T. vulgare, var. **coeruleovelutinum**, Körn. *Syst. Uebers.* 12 (1873).

A rare variety.

Körnicke's specimens of this variety were obtained from Botanic Gardens and from Vernoe, Turkestan.

According to Werner (*Handb. d. Getr.* ii. 378), the form from Turkestan possesses the following characteristics:

Young shoots, erect, young leaves densely hairy.

Straw, of medium height, 100-110 cm. (39-43 inches) high.

Ear, 9-12 cm. long, narrow, of medium density; awns pale, 10 cm. long.

Empty glume, white, with bluish tinge.

Grain, mealy, yellowish-red, roundish, 7 mm. long, 4 mm. broad.

A winter form is also described by Werner, with upright young shoots and slightly hairy, yellowish-green leaves.

Straw, 115-140 cm. high; thick-walled.

Ear, very lax, narrow, 10-13 cm. long, dark and greyish-blue, with awns 8-10 cm. long.

Grain, flinty, long, and narrow, 8 mm. long, 3 mm. broad.

Both the above forms are very susceptible to rust. Many of their morphological characters suggest a close relationship to *T. turgidum*.

Ears bearded; glumes black, pubescent; grain red.

T. vulgare, var. **fuliginosum**, Körn. *Handb. d. Getr.* i. 48 (1885).

A very rare variety, which Körnicke found only in Botanic Gardens.

Straw, tall, 116-132 cm. (46-52 inches) high, solid.

Ear, 5-7 cm. long, flattish; spikelets 16-20, broader than long.

Empty glume, inflated, black, clothed with fine hairs; upper part of the flowering glume black, lower part reddish.

Grain, mealy, plump, yellow.

Although Metzger refers this to *T. vulgare*, he notes that it possesses some of the features of *T. turgidum*.

The solid straw, broad spikelets, inflated glumes, and plump, rounded, starchy grains suggest close affinity with *T. turgidum*.

Werner (*Handb. d. Getr.* ii. 378) describes a winter form with erect, quadrangular ears 10 cm. long, pale yellow or reddish-yellow glumes, their margins, keel, and apical tooth blue; awns blackish, spreading, 9 cm. long; grain starchy, yellowish-red, oval, 7 mm. long, 4 mm. broad; it appears to be closely allied to *T. turgidum*.

Flaksberger (*Bull. App. Bot.* viii. 197) mentions forms of var. *fuliginosum*, with glumes having black hairs on a yellow ground, occurring in Turkestan and the Tiflis province of Transcaucasia.

Beardless Varieties

As explained elsewhere (p. 104), there are comparatively few varieties of wheats whose flowering glumes are totally devoid of awns, most of the so-called beardless forms having awns varying in length from ·5 to 2·5 cm., those with the longest, which are always found near the apex of the ear, are conveniently described as "tip-bearded."

It is among the beardless varieties that the most prolific wheats are found, and it is largely on this account that these, rather than bearded forms, are grown on the intensively cultivated lands of Western Europe.

The beardless varieties exhibit a much greater range of variability in all their characters than bearded wheats. In regard to the density of the ear, all grades are found in cultivation between the most open, lax ears and the dense Squarehead types. By far the greater number of forms belong to the varieties *lutescens*, *milturum*, and *albidum*.

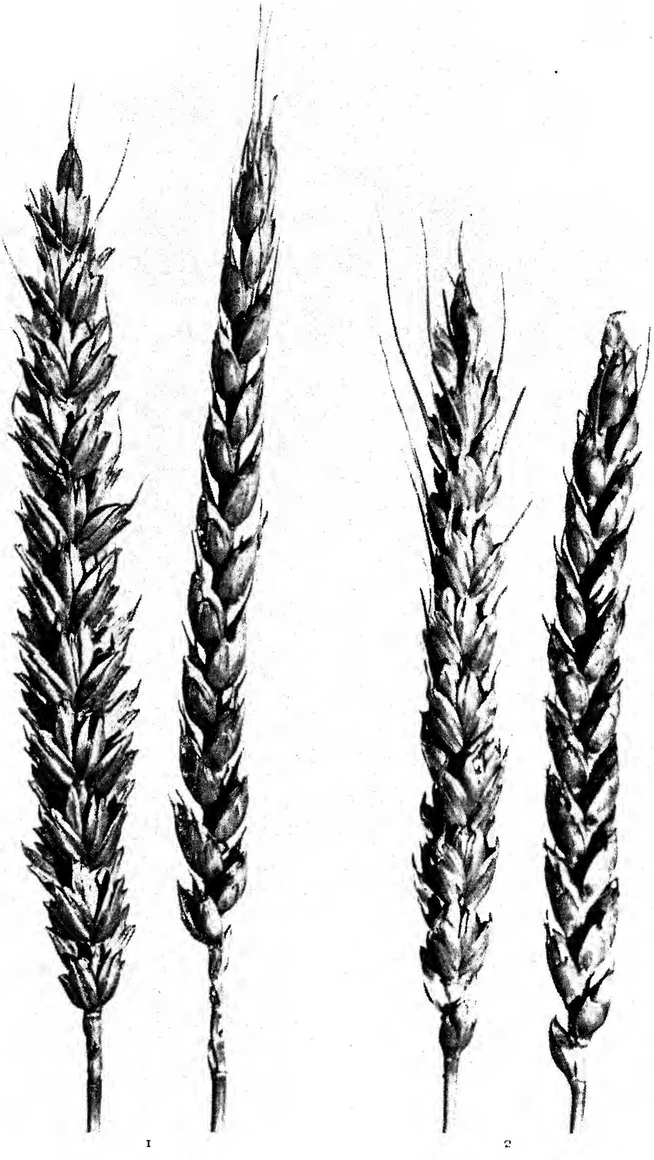

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FIG. 178.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *albidum*. (Russia.) 2. var. *albidum*. (Semiretchensk.)

Ear beardless ; glumes white, glabrous ; grain white.

T. vulgare albidum, Körn. *Handb. d. Getr.* i. 45 (1885).

A widely distributed variety, much more numerous in its forms than the corresponding bearded variety *graecum*. About 150 examples were collected from England, France, Germany, Holland, Russia, South Africa, Persia, India, Australia, New Zealand, and the United States.

They are most commonly cultivated at the present time in dry warm climates, the grain of those from Australia being especially well developed and of a fine white tint.

With the exception of some of the Squarehead type of ear, forms of this variety are rarely grown in Britain or the countries of Western Europe. Like all white-grained wheats, they are extremely liable to sprout in the ear when cut and left in the field in a damp season.

1. **Gentile bianco.**—An early form received from Italy. It comes into ear at Reading about the end of May.

Young shoots, erect.

Straw, slender, tall, 120-128 cm. (48-50 inches) high.

Ear, lax, 10 cm. long; upper spikelets with awns ·5-·7 cm. long; spikelets 20; D = 19-20 (Ear type 2, Fig. 177).

Empty glume, 9-10 mm. long, apex truncate, apical tooth blunt, ·5-1 mm. long (2, Fig. 166).

Grain, large, semi-flinty, 7·3 mm. long, 3·65 mm. broad, 3·45 mm. thick.

Closely similar is **Napoles** from Spain and a form from Chili.

2. An early form, coming into ear May 20-26 at Reading; received from the Central Provinces and United Provinces, India.

Young shoots, erect.

Straw, slender, short to medium, height 75-95 cm. (30-36 inches) long.

Ear, lax, 9-10 cm. long, with awns 5-7 mm. long; spikelets 19-21; D = 20-23.

Empty glume, 9 mm. long; apical tooth blunt, ·5 mm. long.

Grain, semi-flinty, large, plump; 7 mm. long, 3·9 mm. broad, 3·75 mm. thick.

A similar form was received from Australia.

3. **Gandum-i-Kaiseh.**—An early form; received from Persia. It comes into ear at Reading about May 20.

Young shoots, erect.

Ear, erect, 9 cm. long, with awns ·5-1 cm. long; spikelets 19; D = 22 (Ear type 2, Fig. 178).

Empty glume, 8 mm. long, keeled to base, broad, apex with incurved claw-like tooth, 2 mm. long (1, Fig. 166).

Grain, large, semi-flinty, plump; 7·2 mm. long, 3·5 mm. broad, 3·55 mm. thick.

4. **Epp.**—A mid-season variety received from Germany.

Young shoots, prostrate.

Straw, very tall, 142 cm. (about 56 inches) high.

Ear, 10-11 cm. long, with spreading spikelets and short awns, 3-5 mm. long; spikelets 21-23; D=22 (Ear type 2, Fig. 177).

Empty glume, 9 mm. long, keeled to the base, apex broad; apical tooth blunt, ·5 mm. long (2, 11, Fig. 166).

Grain, semi-flinty, large, loosely held in the glumes; 7 mm. long, 3·95 mm. broad, 3·7 mm. thick.

A similar form with laxer ears (D=17) from Russia.

5. **Fenton.**—A late form coming into ear at Reading about June 20. Introduced by G. Hope of Fenton Barns, East Lothian, Scotland, who found it in a quarry on his farm in 1835. It was much grown down to 1870, about which date it began to be supplanted by Squarehead wheat.

Young shoots, prostrate.

Straw, somewhat slender, tall, 127 cm. (about 50 inches) high.

Ear, lax, tapering towards both ends, about 10 cm. long, with a few awns 1 cm. long near the apex; spikelets 20-23; D=21-23 (Ear type 1, Fig. 178).

Empty glume, 8 mm. long, apex truncate, apical tooth blunt, ·5-1 mm. long (6, 9, Fig. 166).

Grain, flinty, plump, 6 mm. long, 3·5 mm. broad, 3·2 mm. thick.

The following forms completely resemble this variety in habit of growth, time of ripening, and morphological characters of the straw and ear:

Chidham, a famous Old English wheat found in a hedge at Chidham in Sussex in 1789 or 1790, **Trump**, **Zeeland White**, **Markischer**, and some Russian forms.

6. **Solid-straw White Tuscan.**—A form with solid straw and empty glumes resembling those of *T. Spelta*; received from New Zealand, the United States, and Austria.

Young shoots, erect.

Straw, somewhat slender, very tall, 120-132 cm. (48-52 inches) high, solid.

Ear, 9-10 cm. long; spikelets 20; D=20-23 (Ear type 2, Fig. 181).

Empty glume, rigid, 8 mm. long, keeled to the base; apex broad, truncate; apical tooth blunt, ·5-1 mm. long (10, 11, Fig. 166); lower and middle flowering glumes with claw-like awns 5-6 mm. long; awns of the apical spikelets 2-5 cm. long.

Grain, amber, flinty, 7 mm. long, 3·6 mm. broad, 3·5 mm. thick.

7. **Bobs.**—An early form received from Australia. It comes into ear at Reading about the end of May.

Young shoots, erect or semi-erect.

Straw, somewhat slender, of medium height, 109-114 cm. (about 43-45 inches) high.

Ear, 9-10 cm. long, completely awnless, tapered slightly; spikelets 20-22; D=20-22 (Ear type 1, Fig. 180).

Empty glume, rigid, 8 mm. long, apex truncate, apical tooth blunt, ·5-1 mm. long (22, Fig. 166).

Grain, flinty, 6·5 mm. long, 3·6 mm. broad, 3·25 mm. thick.

Closely similar Australian forms with semi-erect young shoots, completely

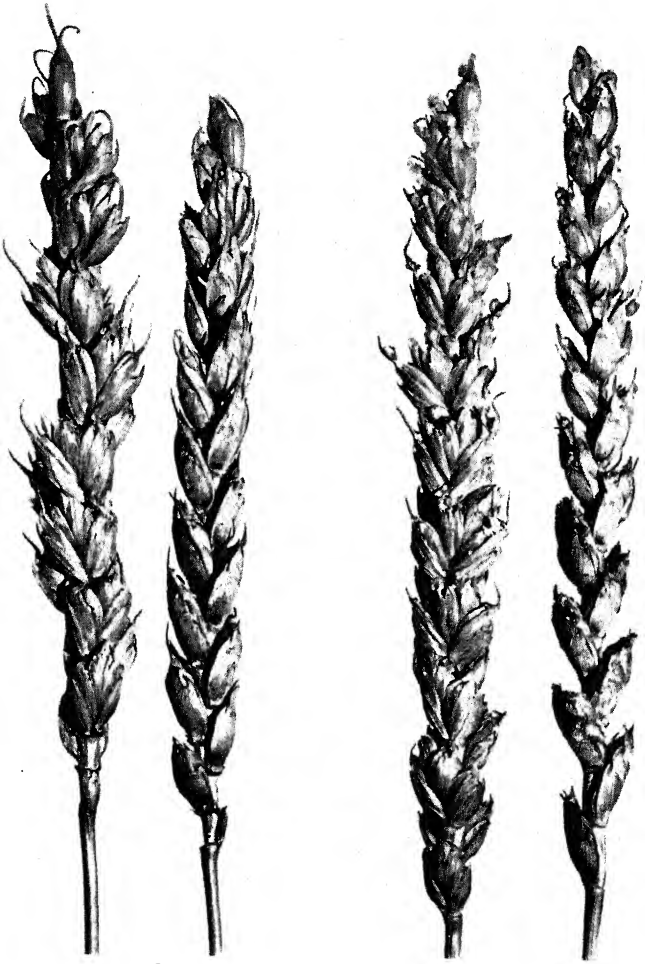

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FIG. 179.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *lutescens*. (Persia.)

2. var. *albidum*. (Semiretchensk.)

beardless ears with rigid truncate empty glumes resembling those of *T. Spelta* are **Warren, Thew, Comeback,** and **Jonathan**, the latter with more hairs on the young leaf-surfaces and somewhat denser ears (D = 24).

A form received from Rhodesia under the name **Nobbs** is similar to these.

8. **White Victoria.**—A mid-season form received from England and France. It comes into ear at Reading about June 10.

Young shoots, semi-erect.

Straw, tall, 127 cm. (about 50 inches) high.

Ear, somewhat lax, 10 cm. long with a few awns, ·5-1 cm. long near the apex; spikelets 22-25; D = 22-25 (Ear type 1, Fig. 188).

Empty glume, 8 cm. long, apex rather narrow, apical tooth blunt, 1 mm. long (Form 16, Fig. 166).

Grain, semi-flinty, plump, 5·9-6 mm. long, 3·7 mm. broad, 2·9 mm. thick.

Very similar is **Blanc de Flandres** from France with slightly longer awns on the apical spikelets.

White Treasure from New Zealand, **Hybrid Bordier** from France, and **White Japhet** from Cape Colony, South Africa, are somewhat similar forms with larger grains (6·5 mm. long, 4·1 mm. broad, 3·7 mm. thick).

9. **Hallett's Pedigree White.**—An Old English mid-season form.

Young shoots, erect or semi-erect.

Straw, tall, 127 cm. (50 inches) high, pink.

Ear, 9 cm. long, slightly tapered with a few awns, ·5 cm. long near the apex; spikelets 26; D = 29-30. (Ear type 1, Fig. 188).

Empty glume, 8 mm. long, apex narrow, apical tooth blunt, ·5-1 mm. long (7, Fig. 166).

Grain, semi-flinty, 6·25 mm. long, 3·9 mm. broad, 3·2 mm. thick.

10. **Mansholt's Dikkop, No. 1.**—A very late form from Holland.

Young shoots, prostrate.

Straw, stout, of medium height, 102 cm. (40 inches) high.

Ear, 9 cm. long with a few awns at the tip about ·5 cm. long; spikelets 23; D = 27 (Ear type 2, Fig. 188).

Empty glume, 9 cm. long, apex broad, truncate, apical tooth blunt, ·5 mm. long (7, Fig. 166, with broad apex).

Grain, semi-flinty, 6·85 mm. long, 3·8 mm. broad, 3·4 mm. thick.

11. **Wilhelmina.**—A late prolific form received from Holland; grown also in England.

Young shoots, prostrate.

Straw, of medium height, 96-102 cm. (38-40 inches) high.

Ear, dense, 7-8 cm. long, 15 mm. across the face, 12-14 mm. across the side; spikelets 24-26; D = 28-32 (Ear type 2, Fig. 189).

Empty glume, 8-9 mm. long; apical tooth blunt, 1 mm. long; lower flowering glumes with short incurved tooth, apical flowering glumes with awns 1-1·5 cm. long.

Grain, white, opaque, mealy; 6·8 mm. long, 4 mm. broad, 3-3·2 mm. thick.

Similar to this is **Willem I.** from Holland, **Victor, Stand-up, Essex Hybrid**

from England, and **Blanc à paille raide** from France; all come into ear at Reading about the last week of June.

12. **Million.**—Received from Holland.

Young shoots, prostrate.

Straw, of medium height, 96-102 cm. (38-40 inches) high.

Ear, dense, 7-8 cm. long, 15 mm. across the face, 12-14 mm. across the side; spikelets 24-27; D=34-38 (Ear type 1, Fig. 190).

Empty glume, 8-9 mm. long, apical tooth blunt, 1 mm. long (7, 11, Fig. 166); flowering glumes of upper spikelets with awns ·5-1·5 cm. long.

Grain, creamy-white, usually semi-flinty; 6·8 mm. long, 4 mm. broad, 3·3 mm. thick.

White Monarch, Mark Lane, and **Emperor**, from England, closely resemble this form. They are all very late prolific varieties, which do not come into ear at Reading until about the last week in June.

Ear beardless; glumes white, glabrous; grain red.

T. vulgare, var. **lutescens**, Körn. *Handb. d. Getr.* i. 45 (1885).

This variety possesses the largest number of forms of any of the varieties of *T. vulgare*.

About 250 forms were collected, examples being obtained from every wheat-growing country. The majority, however, came from Western Europe, Australia, and New Zealand, countries in which bearded varieties are not esteemed.

Some of the forms have long lax ears, others are of the dense Squarehead type, and between these extremes are found all grades of ear-length and density.

Similar gradation occurs among the numerous forms in respect of earliness and lateness of growth, tallness and shortness of straw, and examples of this variety are found in all the groups mentioned on pp. 270-272.

1. **Granella de Carpegna.**—An early form received from Spain, with similar forms having empty glumes keeled to the base. These come into ear at Reading at the beginning of June.

Young shoots, erect.

Straw, stout, of medium height, 112 cm. (about 44 inches) high.

Ear, very lax, 11-13 cm. long; upper spikelets with awns 1-1·5 cm. long; spikelets 20; D=17 (Ear type 1, Fig. 177).

Empty glume, 10 mm. long (6, 8, Fig. 166).

Grain, semi-flinty, 7 mm. long, 3·65 mm. broad, 3 mm. thick.

2. A common winter (Azima) wheat received from Russia with characteristic velvety young leaves and empty glumes keeled to the base. It is early at Reading, coming into ear during the first week of June.

Young shoots, erect.

Straw, somewhat slender, tall, 120-128 cm. (48-50 inches) high.

Ear, lax, 11-12 cm. long; upper spikelets with awns 1 cm. long; spikelets 19-21; D=19-22 (Ear type 2, Fig. 181).

Empty glume, 10 mm. long, keeled to the base (Forms 5, 11, 22, Fig. 166).

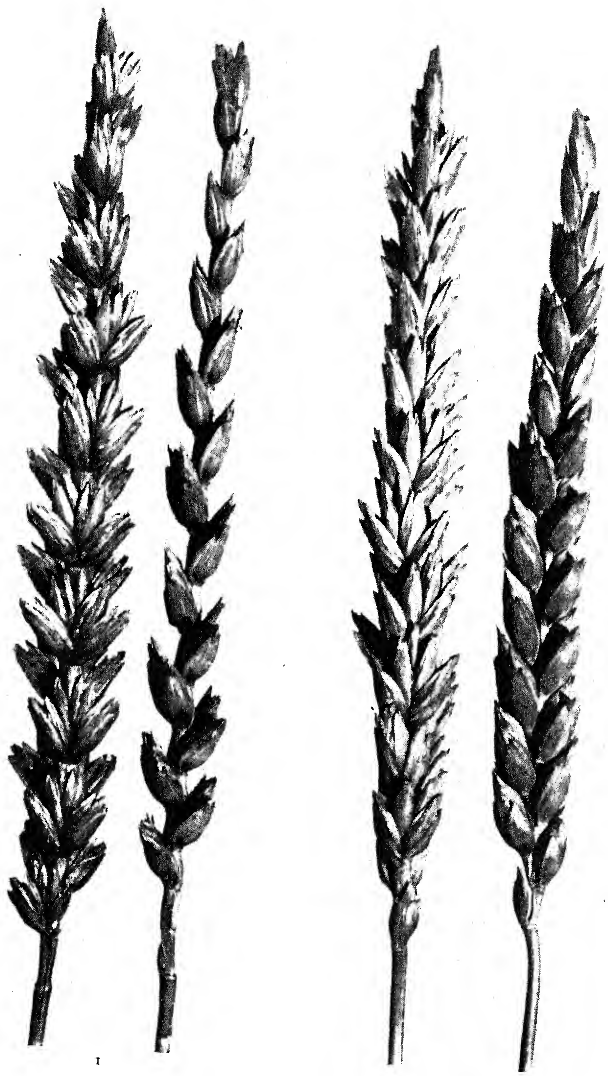

FIG. 180.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *lutescens*. (Japan.)

2. var. *lutescens*. (Cedar.)

Grain, flinty, 7·3-7·5 mm. long, 3·5 mm. broad, 3·15 mm. thick.

Similar forms were received also from Manchuria, Austria, Hungary, and Germany.

3. **Solid-straw Red Tuscan.**—A solid-strawed form of *T. vulgare* received from New Zealand. It comes into ear at Reading about June 10.

Young shoots, erect or semi-erect.

Straw, slender, solid, of medium height, 96-102 cm. (38-40 inches) high.

Ear, lax, 9-10 cm. long; upper spikelets with awns 1-2 cm. long; spikelets 20; D = 22 (Ear type 1, Fig. 178).

Empty glume, 8 mm. long, keeled to the base, with broad apex; apical tooth 1 mm. long (2, Fig. 166).

Grain, mealy, 6·5 mm. long, 3·2 mm. broad, 3 mm. thick.

4. **Frenisburg.**—Received from Switzerland. It comes into ear at Reading, June 10-11.

Young shoots, prostrate.

Straw, slender, tall, 125-135 cm. (48-52 inches) high.

Ear, lax, 9-10 cm. long; upper spikelets with awns 1 cm. long; spikelets 22; D = 22 (Ear type 1, Fig. 178).

Empty glume, 8 mm. long, keeled to the base (Forms 9, 15, Fig. 166).

Grain, flinty, 6·2 mm. long, 3·25 mm. broad, 2·95 mm. thick.

5. **Red Fife.**—A famous wheat grown extensively in Canada and the United States. Its grain is of high quality for bread-making. The original plant was derived from a sample sent by a friend in Glasgow to David Fife in Ontario, Canada, about 1842. The sample is said to have been taken from a cargo shipped from Dantzig to Glasgow. Fife wheat very closely resembles some forms from Galicia and Western Russia, and probably came from this region.

Young shoots, prostrate.

Straw, slender, medium height, 95-115 cm. (about 38-45 inches).

Ear, lax, 10-11 cm. long, upper spikelets usually with awns 10-12 mm. long; spikelets 20-22; D = 18-20 (Ear type 1, Fig. 178).

Empty glume, 9-10 mm. long, apex narrow, tooth blunt (6, 9, Fig. 166).

Grain, flinty, apex blunt, 6·5-6·8 mm. long, 3·4 mm. broad, 3·3 mm. thick.

Marquis wheat is supposed to be derived from a cross between an Indian early wheat and Fife. It closely resembles the latter, but its straw, ears, glumes, and grain are slightly shorter (Ear type 2, Fig. 181). It ripens its grain from four to seven days earlier than Fife, and on this account has supplanted the latter wheat in districts liable to early droughts and frosts.

6. **Gandum-i-Kaiseh.**—A distinct and early form received from Persia. It comes into ear at Reading about May 22.

Young shoots, erect.

Straw, of medium height, 91-96 cm. (36-38 inches) high.

Ear, lax, 9-11 cm. long; upper spikelets with curved hook-like awns about 1 cm. long; spikelets 20; D = 21-22 (Ear type 1, Fig. 179).

Empty glume, 9 mm. long, inflated, apex broad with apical tooth 1-2 mm. long, bent inwards (2, 3, Fig. 166).

Grain, large, semi-flinty, 8·4 mm. long, 3·6 mm. broad, 3·5 mm. thick.

7. **Frankenstein.**—A late form received from Germany. It comes into ear at Reading about June 23.

Young shoots, prostrate.

Straw, somewhat slender, tall, 125 cm. (about 49 inches) high.

Ear, narrow, 10-11 cm. long; upper spikelets with awns ·5-1 cm. long; spikelets 27; D = 26 (Ear type 1, Fig. 181).

Empty glume, 9-10 mm. long, apex broad (22, Fig. 166).

Grain, flinty, 7 mm. long, 3·7 mm. broad, 3·2 mm. thick.

Closely resembling this form are the tip-bearded **Saumur de Mars** from France and the English **Trump.**

8. **Geldersche.**—A late form received from Holland. It comes into ear about June 22.

Young shoots, prostrate.

Straw, somewhat slender, tall, 115 cm. (45 inches) high.

Ear, 10-11 cm. long; upper spikelets with awns 1-1·5 cm. long; spikelets 24; D = 24 (Ear types 1, Fig. 178; 2, Fig. 181).

Empty glume, 8 mm. long (Forms 20, 22, Fig. 166).

Grain, flinty, 6·5 mm. long, 3·25 mm. broad, 3·1 mm. thick.

9. **Cedar.**—An Australian form.

Young shoots, semi-erect.

Straw, medium height, 90-102 cm. (36-40 inches) high, hollow with thick walls.

Ear, lax, rigid, 10-12 cm. long, 12 mm. across the face, 10 mm. across the side; flowering glumes quite awnless; spikelets 20-22; D = about 20 (Ear type 2, Fig. 180).

Empty glume, 10 mm. long, apex truncate (11, Fig. 166).

Grain, flinty, apex blunt, 6·4 mm. long, 3·8 mm. broad, 3·2 mm. thick.

10. **Hybrid Inversable.**—A late form received from France. It comes into ear at Reading about June 20.

Young shoots, semi-erect.

Straw, stiff, of medium height, 94 cm. (about 37 inches) high.

Ear, 9 cm. long; upper spikelets with awns 1-2·5 cm. long; spikelets 20; D = 23 (Ear type 1, Fig. 187).

Empty glume, 9 mm. long (7, Fig. 166).

Grain, semi-flinty, 7 mm. long, 4 mm. broad, 3·2 mm. thick.

Bon Fermier from France, **Hadmersleben** from Germany, and the English **Dreadnought** are similar to this.

11. **Trigo Regadio.**—An early form received from Spain.

Young shoots, erect.

Straw, of medium height, 96-102 cm. (38-40 inches) high.

Ear, 8-9 cm. long; upper spikelets with awns ·5-1 cm. long; awns or teeth of the lower flowering glumes curved inwards; spikelets 22; D = 23 (Ear type 1, Fig. 187).

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FIG. 181.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *lutescens*. (Frankenstein.)

2. var. *lutescens*. (Chidham de Mars.)

Empty glume, 8 mm. long (1, 2, Fig. 166).

Grain, semi-flinty, 7 mm. long, 4·1 mm. broad, 3·6 mm. thick.

A similar form was also received from Germany under the name **Tüchtiger Landwirth.**

12. **Red Japhet.**—An early form received from France. It comes into ear at Reading about June 9.

Young shoots, erect.

Straw, of medium height, 115 cm. (about 45 inches) high.

Ear, 9-10 cm. long ; apical spikelets with awns ·5 cm. long ; teeth of lower flowering glumes curved inwards ; spikelets 20 ; D=22 (Ear type 1, Fig. 187).

Empty glume, 8 mm. long, apex truncate (22, Fig. 166).

Grain, semi-flinty, 6·6 mm. long, 4·2 mm. broad, 3·85 mm. thick.

Resembling it is **Red Marvel.**

13. **Victoria.**—A late form received from France. It comes into ear at Reading, June 20-24.

Young shoots, prostrate.

Straw, tall, 135 cm. (about 52 inches) high.

Ear, 10 cm. long ; upper spikelets with awns not more than ·5 cm. long ; spikelets 24-26 ; D=26 (Ear type 1, Fig. 188).

Empty glume, 8-9 mm. long (6, Fig. 166).

Grain, mealy, 6·3 mm. long, 4 mm. broad, 3·4 mm. thick.

Similar forms are **Essex Conqueror, Street's Imperial, Kinver Red, Model Red**, and **Swan.**

14. **Tystofte Standhvete.**—A very late form received from Denmark. It comes into ear at Reading about June 23.

Young shoots, prostrate.

Straw, of medium height, 102 cm. (about 40 inches) high.

Ear, 7-8 cm. long ; upper spikelets with awns 1-2 cm. long ; spikelets 19-20 ; D=27 (Ear type 2, Fig. 188).

Empty glume, 8 mm. long (9, 11, Fig. 166).

Grain, semi-flinty, 6·25 mm. long, 3·25 mm. broad, 3·0 mm. thick.

Somewhat similar are **Tystofte Smaahvete** from Denmark, **Gneisendorf** from Austria, and **English White Straw Red.**

15. **Svalöf Grenadier.**—A late form received from Sweden. It comes into ear at Reading about June 24.

Young shoots, prostrate.

Straw, of medium height, 96 cm. (about 38 inches) high.

Ear, 9-10 cm. long ; upper spikelets with awns about 1 cm. long, the short awns of the lower spikelets curved inwards ; spikelets 23 ; D=25-27 (1, 2, Fig. 188).

Empty glume, 9 mm. long (11, Fig. 166).

Grain, semi-flinty, 6·6 mm. long, 3·7 mm. broad, 3·1 mm. thick.

Similar to this are **Mettel's Squarehead** and others from Germany and Austria.

16. **Squarehead.**—A late, very prolific English wheat very widely grown throughout Western Europe since 1870 on account of its stiff straw and high yield. It comes into ear at Reading about June 20. Breymann (*Landw. Jahrb.* 786, 1878) was informed by Samuel D. Shirreff that it was discovered by a Mr. Taylor in a field of Victoria wheat in Yorkshire about 1868. From 1870 it was very extensively grown and sold by C. Scholey, Eastoft Grange, Goole, Yorkshire, who is sometimes credited with its discovery. It was introduced into Denmark by a pupil of S. D. Shirreff in 1874, and from thence into Germany. Later it spread to Holland, Belgium, and France.

Previous to 1870, typical Squarehead wheats were grown as early as 1839 under the names **Suffolk Thickset** and **New Red Norfolk** or **Hickling's Prolific**, and specimens of these collected in 1839 and 1841 are in the Collection of the Royal Agricultural Society of England (Nos. 136 and 245). Hickling's Prolific was discovered in 1830 by Samuel Hickling of Cawston, Aylsham, Norfolk, and continued to be grown for some considerable time. Whether the more modern Squarehead of Taylor, Scholey, and Shirreff was a derivative of Hickling's wheat, or a new and independent mutation or product of hybridisation cannot be determined.

Forms resembling Squarehead appear in the F_2 and subsequent generations of hybrids of lax-eared *vulgare* wheats with *T. compactum*.

Squarehead.

Young shoots, prostrate.

Straw, of medium height, 105 cm. (about 41 inches) high.

Ear, dense, square, 8·5 cm. long; upper spikelets with awns 1-1·5 cm. long; spikelets 24; D = 32 (Ear type 2, Fig. 189).

Empty glume, 9 mm. long (6, 9, Fig. 166).

Grain, semi-flinty, 6·5 mm. long, 3·6 mm. broad, 3·25 mm. thick.

Numerous selections have been made of Squarehead wheat in all the countries previously named. These differ slightly in morphological characters, such as form of empty glume, the length of the awn on the flowering glumes near the apex of the ear, and in ear density.

Nearest the original form are **Browick Greychaff**, **Leutewitz**, and **Beseler's Squareheads** from Germany. **Criewener Squarehead** from Germany and Austria and **Essex Squarehead** have shorter awns (·5 cm. long). Several of the Swedish **Svalöf Squareheads**, **Strube's Squarehead**, and **English Rent Payer**, which closely resemble each other, have denser ears (D = 36-37).

Ear beardless; glumes white, pubescent; grain white.

T. vulgare, var. **leucospermum**, Körn. *Syst. Uebers.* 10 (1873).

A widely distributed variety.

1. An early form received from the Punjab, the United Provinces, and other parts of India. It comes into ear at Reading at the end of May.

Young shoots, erect.

Straw, slender, short to medium height, 88-102 cm. (35-40 inches); leaves blue-green.

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FIG. 182.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *milturum*. (Russia.) 2. var. *milturum*. (Chubut.)

Ear, lax, 8-9 cm. long; spikelets 17-19, spreading; D = 18-22 (Ear types 2, Fig. 180; 1, Fig. 181).

Empty glume, thin, 9 mm. long, narrow at apex; apical tooth acute, 1-2 mm. long; flowering glumes often have slender awns 5-10 mm. long (23, Fig. 166).

Grain, flinty, apex truncate, 6·6 mm. long, 3·65 mm. broad, 3 mm. thick.

A similar early form with somewhat denser semi-bearded ears (D = 21, awns at the apex of the ear up to 2 cm. long) was obtained from the Transvaal, South Africa, under the name **Wit Wol Koren.**

2. A spring form received from Persia under the name **Gandum Kamisheh.**

Young shoots, erect.

Straw, slender; leaves glaucous.

Ear, lax, 9-10 cm. long; spikelets 17, inflated; D = 19 (Ear type 1, Fig. 179).

Empty glumes, oval, 9 mm. long; apical tooth curved, slender, 1-3 mm. long; flowering glumes of upper spikelets with tortuose awns 1-2·5 cm. long (Form 3, Fig. 166).

Grain, long, semi-opaque, with highly arched dorsal side; 7·8 mm. long, 3·6 mm. broad, 3·7 mm. thick.

3. **Pearl.**—A winter wheat received from New Zealand.

Young shoots, prostrate.

Straw, tall, 112-118 cm. (44-47 inches) high.

Ear, 8 cm. long; spikelets 21-23; D = 27-28 (Ear type 1, Fig. 188, but shorter).

Empty glume, 8 mm. long; apical tooth blunt, 1 mm. long; flowering glumes of apical spikelets with awns 5-12 mm. long (Form 9, Fig. 166).

Grain, short, plump, semi-flinty; 5·8 mm. long, 3·65 mm. broad, 3·0 mm. thick.

Closely similar are **Snowdrop** and **Velvet Chaff**, also from New Zealand, and **Pudel** wheat from Sweden.

4. **Blanc à duvet** from France is a winter form similar to Pearl in the length of its ear and straw and in the habit of its shoots, but possesses a somewhat narrower empty glume 10 mm. long, the apical tooth 1-1·5 mm. long (15, Fig. 166), and a more elongated flinty grain 6·15 mm. long, 3·5 mm. broad, 3·0 mm. thick.

The **English Old Hoary**, **Essex Rough Chaff**, and **Velvet Chaff White**, which were formerly much grown in this country, closely resemble this form.

5. Early spring forms with erect young shoots, narrow tapering ears 9-10 cm. long, D = 23-25, and grain 6·5 mm. long, 3·65 mm. broad, 3·55 mm. thick have been obtained from Rhodesia, Australia, and New Zealand. They come into ear at Reading in the first week of June.

6. A distinct early form from Asia Minor.

Young shoots, erect or semi-erect.

Straw, short, slender, 80-90 cm. (about 32-36 inches) long.

Ear, lax, glaucous, with awned tips 8·5-9 cm. long; spikelets 16-18; D = about 20 (Ear type 2, Fig. 181).

Empty glume, 10 mm. long; apex broad; apical tooth blunt and short; flowering glumes of upper spikelets with awns 1-2 cm. long (20, Fig. 166).

Grain, flinty, 7 mm. long, 3·5 mm. broad, 3-4 mm. thick.

Ear beardless; glumes white, pubescent; grain red.

T. vulgare, var. **velutinum**, Körn. *Handb. d. Getr.* i. 45 (1885).

A rare variety. Considerable areas of one or two forms of it are cultivated in the United States.

1. Forms were received from India with characters similar to those of No. 1, var. *leucospermum*, but with red grain.

2. **Haynes' Blue Stem.**—A winter form, received from the United States and Australia.

Young shoots, prostrate or semi-erect.

Straw, soft, weak, of medium weight, short, 90-110 cm. (about 36-44 inches) long; leaves glaucous.

Ear, lax, 10-12 cm. long; spikelets 19-23; D = 19-22 (Ear type 1, Fig. 178, but usually shorter).

Empty glume, 9 mm. long; apical tooth ·5 mm. long, blunt (21, Fig. 166); flowering glumes of upper spikelets often have an awn 1-2·5 cm. long.

Grain, flinty, 6·4 mm. long, 3·2 mm. broad, 2·9 mm. thick.

Similar late forms also from Switzerland, Holland, and Sweden. **Jones' Winter Fife, Silver King**, and **Oakley** from the United States are also similar but somewhat earlier, with shorter awns at the tip of the ear.

3. **De Haie**, and some selections and hybrids from Germany and Sweden with shorter and denser ear (7-8 cm. long; D = 24-30), belong to this variety.

They are all late forms with prostrate young shoots and stout straw of medium height.

Ear beardless; glumes red, glabrous; grain white.

T. vulgare, var. **alborubrum**, Körn. *Syst. Uebers.* 10 (1873).

A widely distributed variety chiefly grown in warm climates.

About fifty named forms were obtained, the majority from Spain, Russia, Turkey, India, South Africa, Australia, New Zealand, Canada, and the United States.

Most of these forms are Spring wheats with lax tapering ears, some of them markedly "tip-bearded." One or two forms with much denser ears came from Holland and France.

1. **Punjab 21.**—A very early form received from India. It comes into ear at Reading about May 20.

Young shoots, erect.

Straw, slender, of medium height, 88-115 cm. (about 32-45 inches) high.

Ear, lax, narrow, 8-9 cm. long, square, about 10 mm. across the sides; D = 20.

Empty glume, 10 mm. long, keeled to the base; apical tooth acute, 1 mm. long (5, Fig. 166); apex of flowering glume narrow, acute.

FIG. 183.—BREAD WHEAT (*T. vulgare*, Host).

var. *milturum*.
(Abyssinia.)

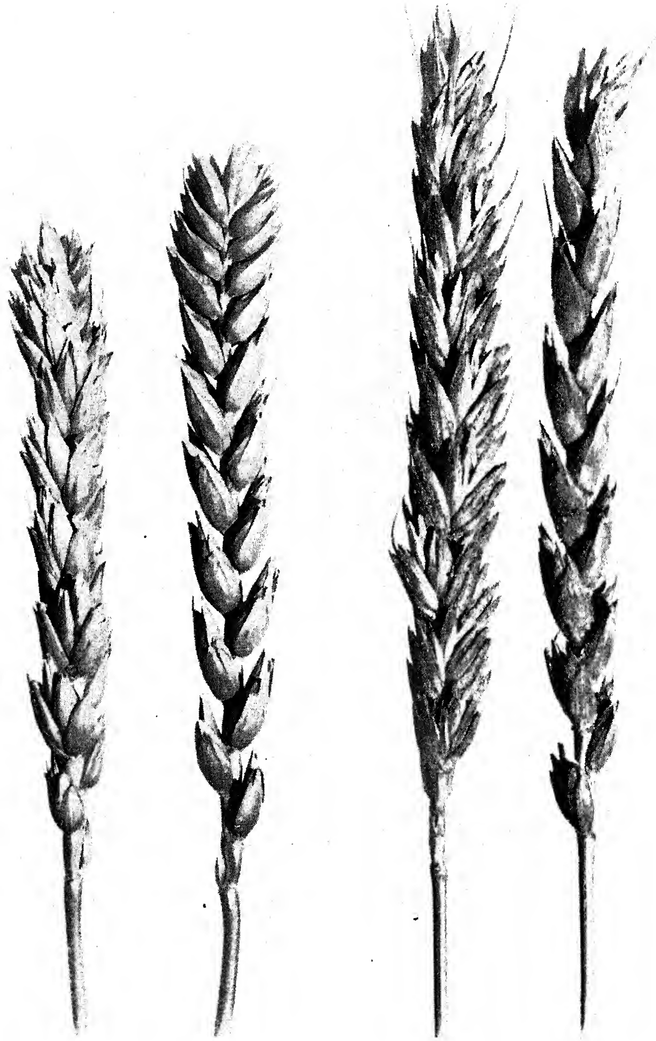

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FIG. 184.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *lutescens*. (India.)

2. var. *Delfii*. (Sind.)

Grain, flinty, with prominent dorsal ridge; apex truncate; 7·2 mm. long, 3·6 mm. broad, 3·2 mm. thick.

A somewhat similar form, but ten to fourteen days later with denser ears (D = 23), is Punjab 20, received from India.

2. **John Brown.**—An early form received from Australia. It comes into ear at Reading about June 2.

Young shoots, erect.

Straw, stiff, 90-102 cm. (about 36-40 inches) high.

Ear, lax, 10 cm. long; upper spikelets with awns ·5 to ·75 cm. long; spikelets 18-20; D = 20-22 (Ear type 2, Fig. 180, with short awns).

Empty glume, 8 mm. long; apex broad, truncate; apical tooth ·5 mm. long, blunt (11, Fig. 166).

Grain, long, flinty, 7·3 mm. long, 3·4 mm. broad, 2·8 mm. thick.

Similar to this is **Darling** from the Transvaal.

3. **Xeixa.**—An early form received from Spain. It comes into ear at Reading about June 8.

Young shoots, semi-erect.

Straw, somewhat slender, medium to tall, 122-132 cm. (48-52 inches) high.

Ear, tip-bearded, lax, 11 cm. long; upper spikelets with awns 1·5-3 cm. long; spikelets 19-20; D = 17-20 (Ear type 1, Fig. 178).

Empty glume, 8 mm. long, keeled to the base; apical tooth 1 mm. long (21, Fig. 166).

Grain, flinty; dorsal ridge somewhat prominent; 7-7·3 mm. long, 3·5 mm. broad, 3·55 mm. thick.

Very similar to this but with shorter awns at the apex of the ears are **Nobbs**, **Gluyas**, and **Early Gluyas** from Australia, **Union C** from the Transvaal, and **Odessa** from France and Spain. The Australian and Transvaal forms are earlier than the rest, coming into ear at Reading about the end of May.

A somewhat denser-eared series of prostrate forms (D = 22-23) are **Early Windsor**, **Fortyfold**, **Prize Taker**, **Superlative**, **Mogul**, and **Abundance** from Canada, **Bianchetta** from the Cape, and **Kizildaly** from Turkey.

4. **Red Federation.**—An early form received from Australia. It comes into ear at Reading about May 26.

Young shoots, erect or semi-erect.

Straw, stiff, short, 80-90 cm. (about 32-36 inches) high.

Ear, 10-12 cm. long; spikelets 21-23; D = about 21 (Ear type 1, Fig. 181).

Empty glume, coriaceous, 10 mm. long, somewhat inflated; apical tooth 5 mm. long (10, 11, Fig. 166).

Grain, flinty, 6·25 mm. long, 3 mm. wide, 2·8 mm. thick.

5. A mid-season form received from Russia. It comes into ear at Reading about June 15.

Young shoots, prostrate.

Straw, slender, tall, 121 cm. (about 48 inches) high.

Ear, narrow, lax, 11-12 cm. long; upper spikelets with awns 1-3 cm. long; spikelets 23; D = 20.

Empty glume, 8 mm. long, keeled to the base; apex truncate; apical tooth ·5 mm. long, blunt.

Grain, small, semi-flinty, 6 mm. long, 3·5 mm. broad, 3 mm. thick.

6. **Dattel.**—A mid-season to late form received from France. It comes into ear at Reading about June 17.

Young shoots, prostrate.

Straw, stout, tall, 127 cm. (50 inches) high.

Ear, 10-11 cm. long; spikelets 22; D=21 (Ear type 2, Fig. 186).

Empty glume, 10 mm. long, narrow at apex; apical tooth blunt, ·5 mm. long.

Grain, flinty, 6·4 mm. long, 3·65 mm. broad, 3·1 mm. thick.

7. **Sandomir.**—A mid-season form received from Germany. It comes into ear at Reading about June 17.

Young shoots, prostrate.

Straw, slender, tall, 112 cm. (about 44 inches) high.

Ear, 9-10 cm. long; upper spikelets with awns ·75-1 cm. long; spikelets 21; D=23 (Ear type 2, Fig. 181).

Empty glume, narrow, 8 mm. long; apical tooth blunt, ·5-1 mm. long (22, Fig. 166).

Grain, flinty, 6·1 mm. long, 3·5 mm. broad, 3·3 mm. thick.

8. **Dawson's Golden Chaff.**—A mid-season form received from Canada. It comes into ear at Reading about June 15, and is very susceptible to Yellow Rust.

Young shoots, prostrate or semi-erect.

Straw, somewhat slender, of medium height, 102 cm. (about 40 inches) high.

Ear, 8-9 cm. long; upper spikelets with awns 1-2 cm. long; spikelets 21; D=26 (Ear type 2, Fig. 187).

Empty glume, 9 mm. long; apical tooth ·5 mm. long, blunt (11, Fig. 166).

Grain, flinty, 6·3 mm. long, 3·55 mm. broad, 3·1 mm. thick.

A similar form with darker red glumes was received from New Zealand and from Germany.

9. **White Matador Rood Kop.**—A late form received from Holland. It comes into ear at Reading about June 18.

Young shoots, prostrate.

Straw, stout, tall, 121 cm. (about 48 inches) high.

Ear, dense, 8 cm. long; spikelets 22; D=29 (Ear type 2, Fig. 188).

Empty glume, 8 mm. long; apex truncate; apical tooth ·5 mm. long, blunt (5, 9, Fig. 166).

Grain, semi-flinty, 6·4 mm. long, 3·45 mm. broad, 3 mm. thick.

Ear beardless; glumes red, glabrous; grain red.

T. vulgare, var. **milturum**, Körn. *Handb. d. Getr.* i. 45 (1885).

This is one of the most widely distributed varieties of *T. vulgare*, and embraces a large number of forms. About 180 forms have been grown at Reading, the largest proportion being obtained from Western Europe, although examples are found in almost every wheat-growing country.

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FIG. 185.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *Delfii*. (Sonora.)

2. var. *milturum*. (Hongrie rouge.)

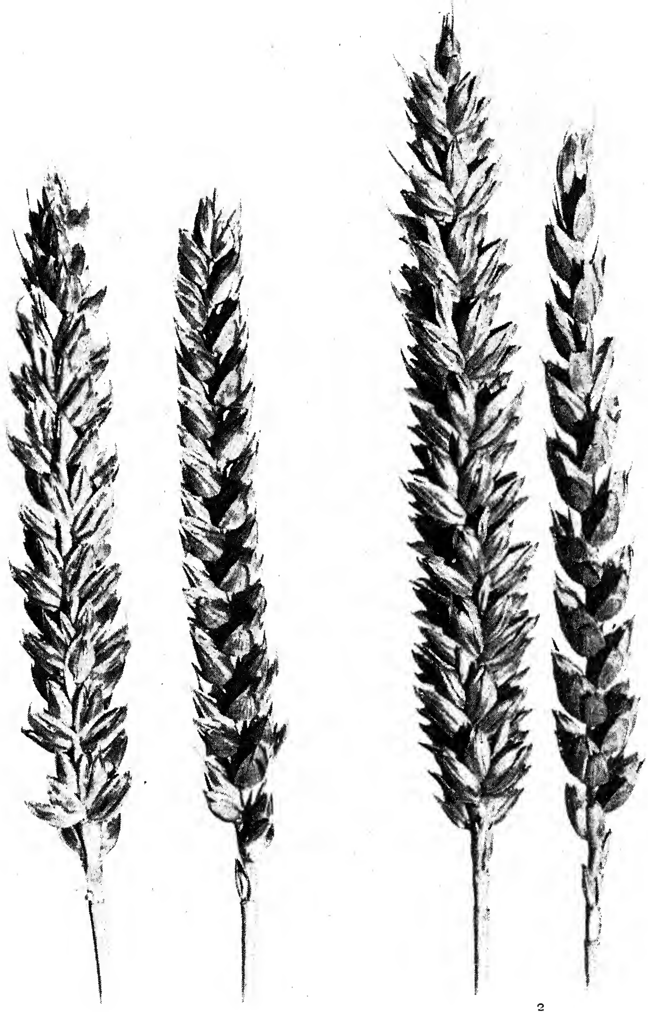

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FIG. 186.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *milturum*. (China.)

2. var. *milturum*. (Lammas.)

Forms with lax and moderately dense ears are equally common ; those with the Squarehead type of ear are much less numerous in this variety than in the vars. *erythrospermum* and *albidum*.

1. **Gallego rapado.**—An early form with very lax tip-bearded ears and stiff glumes, received from Portugal. It comes into ear at Reading about the end of May.

Young shoots, erect.

Straw, strong, tall, 112 cm. (44 inches) high.

Ear, very lax, 10 cm. long, almost square with short inflated spikelets, often irregularly arranged on the rachis, those near the apex having awns 3-4 cm. long ; D = 17 (Ear type 2, Fig. 178).

Empty glume, 7 mm. long, strongly keeled to the base ; apex truncate ; apical tooth blunt, ·5-1 mm. long (2, Fig. 166).

Grain, flinty or semi-flinty, plump, dorsal arch prominent ; 7 mm. long, 3·75 mm. broad, 3·6 mm. thick.

2. **Punjab 22.**—A very early form received from India. It comes into ear at Reading, May 20 to 25.

Young shoots, erect.

Straw, slender, short to medium height, 90-115 cm. (about 35-45 inches) ; leaves generally yellow-green.

Ear, 8-9 cm. long, spikelets frequently arranged irregularly on the rachis ; upper spikelets with awns 1 cm. long ; spikelets 17 ; D = 18-20 (Ear type 2, Fig. 181).

Empty glume, rigid, 8 mm. long, keeled to the base ; apex somewhat broad ; apical tooth acute, 1-1·5 mm. long (5, Fig. 166).

Grain, flinty, 6·8 mm. long, 3·5 mm. broad, 3·1 mm. thick.

Several similar forms ranging in density from 17 to 25 were obtained from Northern India (Cawnpore and the Punjab) ; also from Egypt under the name **Selected Hindi.**

3. **Bordeaux.**—An early form received from France, Spain, and Austria, and from Argentina under the name **French.** It comes into ear at Reading about June 7.

Young shoots, erect.

Straw, stout, medium to tall, 112 cm. (45 inches) high ; leaves glaucous.

Ear, 9·5-10 cm. long, 15 mm. across the face, 10 mm. across the side ; upper spikelets with awns 1-1·5 cm. long ; spikelets 19-20 ; D = 19-22 (Ear type 2, Fig. 177).

Empty glume, stout, 8-9 mm. long, apex truncate, keeled to the base ; apical tooth blunt, ·5-1 mm. long (2, 7, Fig. 166).

Grain, flinty, apex blunt, dorsal side arched ; 6·6 mm. long, 4 mm. broad, 3·65 mm. thick.

Rimpau's Schlanstedt Summer wheat from Germany is similar.

4. **Little Joss.**—A prolific form raised by Professor Biffen at Cambridge. It was obtained from the cross Squarehead's Master × Ghirka.

Young shoots, prostrate.

Straw, moderately stout, medium to tall, 100-115 cm. (about 40-45 inches) high.

Ear, 10-11·5 cm. long; spikelets broad, 22-23; D=20-22 (Ear type 2, Fig. 177, with less tip beard).

Empty glume, about 10 mm. long, keeled to near the base; apical tooth blunt (7, 22, Fig. 166).

Grain, large, semi-flinty, somewhat narrow at the apex; 7 mm. long, 3·9 mm. broad, 3·45 mm. thick.

5. **Touzelle rouge de Provence.**—A widely distributed form received from France. It comes into ear at Reading about June 1-9.

Young shoots, prostrate.

Straw, slender, tall, 120-140 cm. (48-55 inches) high.

Ear, 10-11 cm. long, tapering towards the apex and the base; upper spikelets with awns 1-1·5 cm. long, 2 or 3 basal spikelets often barren; spikelets 21-23; D=20-25 (Ear types 1, Fig. 178; 2, Fig. 181).

Empty glume, 8-9 mm. long, keeled from tip to base; apex truncate; apical tooth blunt, ·5-1 mm. long (2, 21, Fig. 166).

Grain, flinty or semi-flinty, 6·35-7 mm. long, 3·45-3·75 mm. broad, 3·1-3·3 mm. thick.

Resembling it are **Winckler's** and **Horner's Hochfeldt** and **Utendorf** from Switzerland, and a few forms from Austria and Spain.

Closely similar, but with ears somewhat tapering at the apex and narrower spikelets, are a large number of forms from Russia, Argentina, and Hungary, **Stanley** from Canada, and one or two from the United States.

6. A common form included among wheat sent from Russia under the name **Ulka** and **North Russian.**

Young shoots, semi-erect.

Straw, slender, of medium height, 90-105 cm. (35-42 inches).

Ear, slender, tapering; many barren spikelets at base and apex, 10-11·5 cm. long; spikelets 22-25; D=22-25 (Ear types 1, 2, Fig. 182).

Empty glume, 8 mm. long, keeled to the base (8, 9, Fig. 166).

Grain, semi-flinty, 6-7 mm. long, 3·45 mm. broad, 3 mm. thick.

Forms similar to this are frequent in some parts of Argentina.

7. **Golden Drop.**—A late Old English form coming into ear at Reading about June 16 to 20.

Young shoots, prostrate.

Straw, somewhat slender, tall, 120-130 cm. (48-52 inches) high; leaves glaucous.

Ear, 10-11 cm. long, 15 mm. across the face, 9-10 mm. across the side, tapering towards the apex; upper spikelets with awns 1 cm. long; spikelets 23-25; D=20-24 (Ear type 2, Fig. 186).

Empty glume, 9 mm. long; apex somewhat truncate; apical tooth blunt, 1 mm. long (Form 20, Fig. 166).

Grain, flinty or semi-flinty, 5·85 mm. long, 3·5 mm. broad, 2·95-3 mm. thick.

Very similar are a large number of forms which have been received from England, France, Germany, Austria, Sweden, Holland, Switzerland, and Russia.

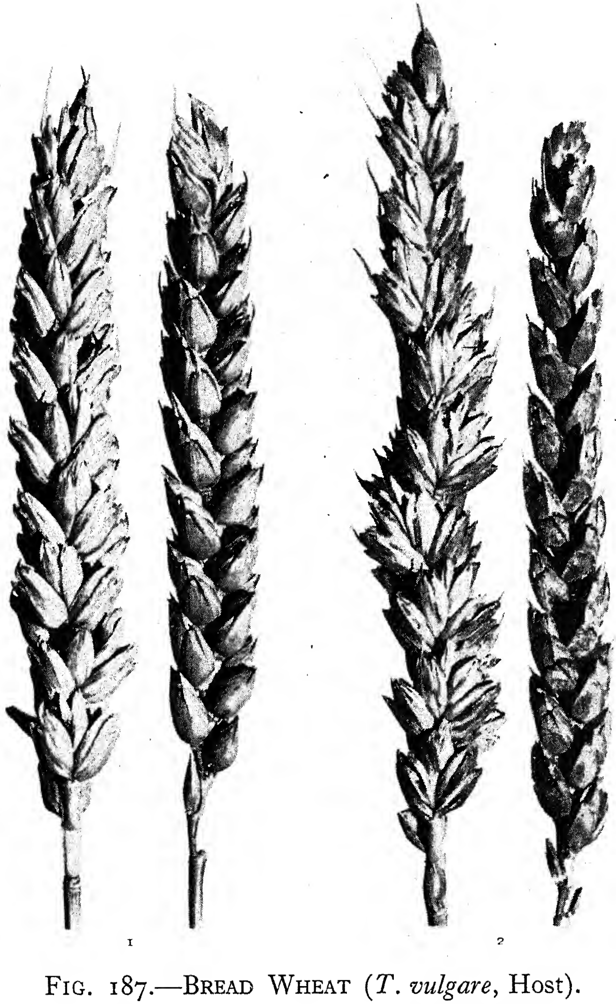

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FIG. 187.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *lutescens*. (Japhet.)

2. var. *cyanothrix*. (Persia.)

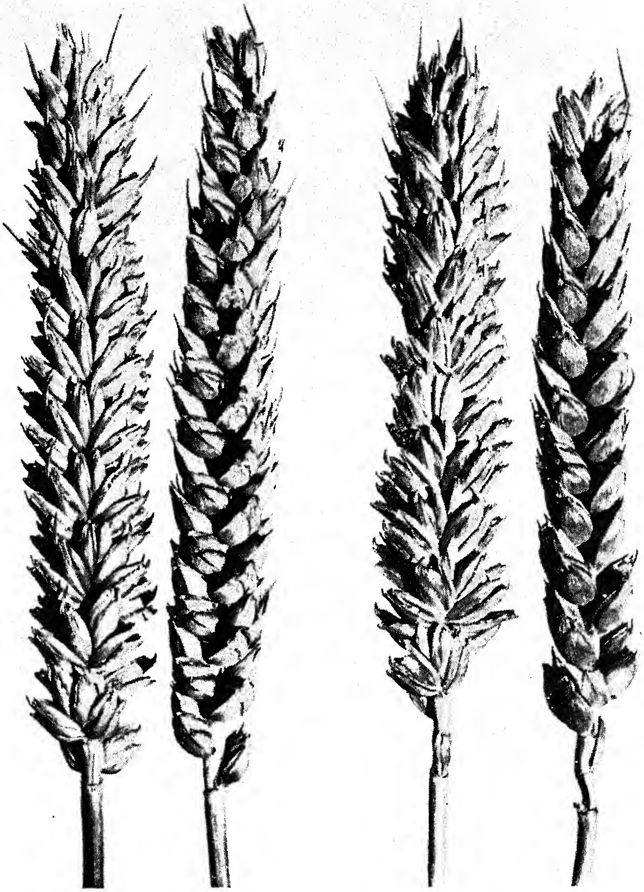

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FIG. 188.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *lutescens*.
(Partridge.)

2. var. *milturum*.
(Squarehead's Master.)

8. **Hongrie Rouge.**—A distinct, long-glumed early form received from France. It comes into ear at Reading about the end of May.

Young shoots, prostrate.

Straw, stout, tall, 137 cm. (54 inches) high ; leaves yellowish-green.

Ear, 9-10·5 cm. long, 18-20 mm. across the face, 22 mm. across the side ; spikelets 25, large, overlapping each other ; D = 24 (Ear type 2, Fig. 185).

Empty glume, 11 mm. long, apical tooth blunt, short.

Grain, flinty, 6·5 mm. long, 3·75 mm. broad, 3·1 mm. thick (7, Fig. 166).

9. **Teverson.**—A prolific late wheat, grown in England and parts of France and Germany. It comes into ear at Reading about June 18.

Young shoots, prostrate.

Straw, stout, tall, 127 cm. (about 50 inches) high ; leaves glaucous.

Ear, dense, 8-9 cm. long, 15 mm. across the face, 10 mm. across the side ; upper spikelets with awns about 1 cm. long ; spikelets 22-24 ; D = 27-30 (Ear type 2, Fig. 188).

Empty glume, 9 mm. long (6, 22, Fig. 166).

Grain, semi-flinty, plump, 6·8 mm. long, 3·75 mm. broad, 3 mm. thick.

Similar to it are **Squarehead's Master, English Standard Red**, and **Red Standup. Red Criewener** from Austria (glume form 7, Fig. 166) also resembles these forms, but is about a week earlier.

Browick is a similar prolific wheat, with denser and somewhat shorter ears.

It was found in 1844 among Annat wheat by R. Banham on his farm at Browick, near Wymondham, Norfolk.

The name Browick is sometimes erroneously applied to Squarehead wheat, a form of var. *lutescens* of similar ear-density.

10. **Kwang T'ou mai.**—A distinct form received from Chungking, China. It yields a large number of small grains and is very early, coming into ear at Reading about May 20.

Young shoots, erect.

Straw, stiff, of medium height, 85-95 cm. (33-38 inches) high ; leaves yellowish-green.

Ear, dense, 8·5 cm. long, 15 mm. across the face, 10 mm. across the side ; spikelets 22, well filled, frequently containing 5 grains in each (Ear type 1, Fig. 186). In some ears the density is uniform (D = 23), in others the lower half is lax and the upper part densely crowded (1, Fig. 189).

Empty glume, thin, broad, 8-9 mm. long, with prominent keel from apex to base and a fine awn 3-5 mm. long (3, 5, Fig. 166).

Grain, dark red with bluntish apex, flinty, small ; 5·7 mm. long, 3·6 mm. broad, 2·8 mm. thick.

Closely allied to this form is **Kyu Shu** from Japan.

Ear beardless ; glumes red, pubescent ; grain white.

T. vulgare, var. **Delfii**, Körn. *Handb. d. Getr.* i. 46 (1885).

A comparatively rare variety confined to warm countries, being obtained only from India, Khorasan (Persia), Egypt, South Africa, and California.

All the forms are very early with the erect spring habit, and belong to Groups I., II., and V.

The Indian forms have yellowish-green leaves, slender straw, and lax ears (D = 17-21), with the spikelets sometimes arranged irregularly on the rachis.

The South African and Californian forms are similar, but have denser ears (D = 22-27).

The Persian forms are distinct from these, having bluish-green leaves, taller straw and ears with broader inflated glumes, and tortuose or hooked awns often 1-2 cm. long.

1. **Sonora.**—An early form received from California. It comes into ear at Reading at the end of May.

Young shoots, erect.

Straw, slender, of medium height, 90-102 cm. (about 36-40 inches) high; leaves pale yellowish-green.

Ear, lax, 9-10 cm. long, 15 mm. across the face, 10-12 mm. across the side; spikelets 21, spreading; D = 22-26 (Ear type 1, Fig. 185).

Empty glume, 8 mm. long; apex narrowed; apical tooth acute, 1·5 mm. long; flowering glumes with awns 3-8 mm. long (15, Fig. 165).

Grain, flinty, 6·2 mm. long, 3·65 mm. broad, 3·15 mm. thick.

Closely similar forms with more hairy leaf-surfaces were obtained from Rhodesia under the name **Victoria**, and from the Transvaal under the name **Rooi Wol Koren.**

A form resembling Sonora, but with laxer ears (D = 20-22) and slender straw about 114 cm. (45 inches) high, was sent from Bombay, the Punjab, and other parts of India.

From Sind, India, I obtained two lax forms (D = 17-18) of var. *Delfii* with ears 10-11 cm. long, one of them possessing awns 1·5-2 cm. long on the flowering glumes of the upper spikelets (Ear type 2, Fig. 184).

2. **Kalkori.**—Sent by Sir Percy Sykes from Khorasan, Persia, where it is grown as a rain-fed or non-irrigated crop.

Young shoots, erect.

Straw, of medium height, 100 cm. (about 39 inches) high; leaves bluish-green.

Ear, lax, 9-10 cm. long; spikelets swollen, 19-20, somewhat irregularly arranged on the rachis; D = 21 (Ear type 1, Fig. 179).

Empty glume, inflated, 8 mm. long, 4-5 mm. broad, more or less keeled to the base; apical tooth 2-3 mm. long, narrow and strongly curved inwards; flowering glumes with short tortuose and hook-like awns 1-2 cm. long (4, Fig. 165).

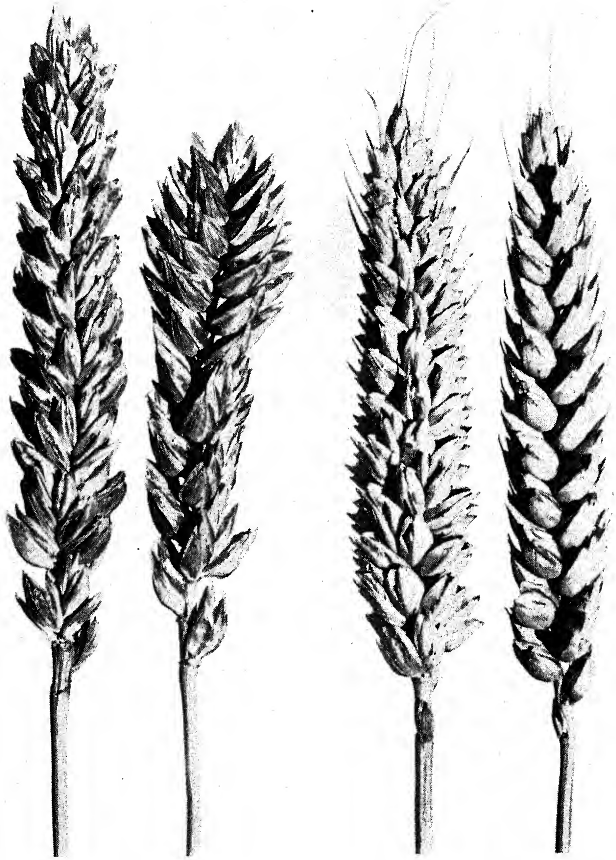
Grain, flinty, 6·5 mm. long, 3·5 mm. broad, 3·35 mm. thick.

Associated with it is a similar semi-bearded form with straighter awns 2-3 cm. long.

Ear beardless; glumes red, pubescent; grain red.

T. vulgare, var. **pyrothrix**, Körn. *Handb. d. Getr.* i. 46 (1885).

1. A very early form, received from the Punjab, the United Provinces, and other parts of India. It comes into ear at Reading about May 20.



I 2

FIG. 189.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *milturum*. (China.)

2. var. *lutescens*. (Squarehead.)

Young shoots, erect.

Straw, slender, short, 76-81 cm. (30-32 inches) high, hollow with thickish walls ; leaves generally pale yellowish-green.

Ear, lax, 9-10 cm. long; spikelets 17-19, spreading, often irregularly arranged; D = 19-21 (Ear type 1, Fig. 185).

Empty glume, firm, 9-10 mm. long, keeled to base, apex narrow ; apical tooth 1·5 mm. long, narrow, curved ; flowering glumes with incurved awns 5-8 mm. long (5, 12, Fig. 166).

Grain, flinty, 7·35 mm. long, 3·4 mm. broad, 3·45 mm. thick ; resembles the grain of *T. durum*.

2. **Seigle.**—A winter form received from France, Germany, and Austria.

Young shoots, prostrate or semi-erect.

Straw, stout, tall, 114-127 cm. (45-50 inches) high.

Ear, 10-12 cm. long ; spikelets 23, spreading ; D = 23 (Ear type 1, Fig. 185).

Empty glume, 9 mm. long, apex narrowed ; apical tooth blunt, ·5 mm. long (22, Fig. 166).

Grain, flinty, dorsal ridge somewhat prominent; 6·6 mm. long, 3·7 mm. broad, 3·4 mm. thick.

A similar form also from New Zealand under the name **Golden Gem.**

3. **Fox.**—A selected sport from Blé à duvet, a French white velvet-chaffed form of var. *leucospermum*.

It tillers extensively, and is especially suited to well-drained wheat soils.

Young shoots, prostrate.

Straw, short, 75-90 cm. (about 30-36 inches) high.

Ear, tapering, 8-9 cm. long ; spikelets 19-22 ; D = 25-27.

Empty glume, 8-9 mm. long, apex narrowed ; apical tooth blunt, 1 mm. long (14, 15, Fig. 166).

Grain, semi-flinty, 6·2 mm. long, 3·6 mm. broad, 3·1 mm. thick.

4. **Chinese.**—A very early form received from Chungking, China. It comes into ear about May 20. Forms with denser, shorter ears (8-9 cm. long; D = 23) have sported from it.

Young shoots, erect.

Straw, stout, of medium height, 84-96 cm. (33-38 inches) high; leaves pale greenish-yellow.

Ear, lax, 11-12 cm. long ; spikelets 20 ; D = 17-18 (Ear type 1, Fig. 186).

Empty glume, oval, 9 cm. long ; apical tooth acute, ·5 mm. long (4, 5, Fig. 166) ; flowering glumes sometimes with awns 5-10 mm. long.

Grain, flinty, small, with truncate apex; 5·8 mm. long, 3·3 mm. broad, 3·0 mm. thick.

Ear beardless ; glumes blackish-yellow, glabrous.

T. vulgare, var. **triste,** Flaksb. *Bull. App. Bot. Petrograd*, iv. 2 (1911).

Flaksberger's type was obtained from Sunpan in the province of Sze-chwan, China.

He describes (1) a spring form, var. *triste Sunpani*, with ears about 9 cm.

long, and short incurved awns; spikelets 14-20; D = 20-25; empty glume inflated, yellow or yellow-blackish with dark brownish-black margins and reddish grain, and (2) a winter form, var. *triste*, and with lax tapering ears (in *Bull. App. Bot.* viii. 194, he states the grains of var. *triste* are white).

Ear beardless; glumes bluish-black; grain red.

T. vulgare, var. **cyanothrix**, Körn. *Handb. d. Getr.* i. 46 (1885).

A very rare variety represented only by one or two forms.

1. **Blue Velvet Chaff.**—A winter late form received from Germany (Haage and Schmidt). The bluish colour of the empty glumes is absent in some seasons, the ear being then a foxy-red tint.

Young shoots, prostrate.

Straw, stout, tall, 127-140 cm. (50-55 inches) high; glaucous.

Ear, tapering, 10-13 cm. long, spikelets 26-28; D = 22-24 (Ear type 2, Fig. 187).

Empty glume, 9-10 mm. long, apex narrow; apical tooth blunt (14, Fig. 166); flowering glumes of the upper spikelets with awns 10-12 mm. long.

Grain, flinty, apex somewhat truncate; 6-8 mm. long, 3·85 mm. broad, 3 mm. thick.

2. A somewhat similar but earlier form received from Persia.

Young shoots, semi-erect.

Straw, stout, tall, very glaucous.

Ear, 8-10 cm. long, square, 10 mm. across the sides or 12 mm. across the face, and 10 mm. across the 2-rowed side; spikelets 18-20; D = 20 (Ear type 2, Fig. 187).

Empty glume, 9-10 mm. long, apex truncate; apical tooth blunt (10, 11, Fig. 166); upper half bluish-black, lower half yellow, in some seasons all yellowish; flowering glumes of the upper spikelets with awns 10-12 mm. long.

Grain, large, semi-flinty, 7-7·5 mm. long, 3·9 mm. broad, 3·5 mm. thick.

Ear beardless; glumes black, pubescent.

T. vulgare, var. **nigrum**, Körn. *Handb. d. Gert.* i. 46 (1885).

This variety was only known to Körnicke through Seringe, who refers to it in his *Céréales européennes* (p. 139) as "Variation N. Touzelle Lammas (noire veloutée)."

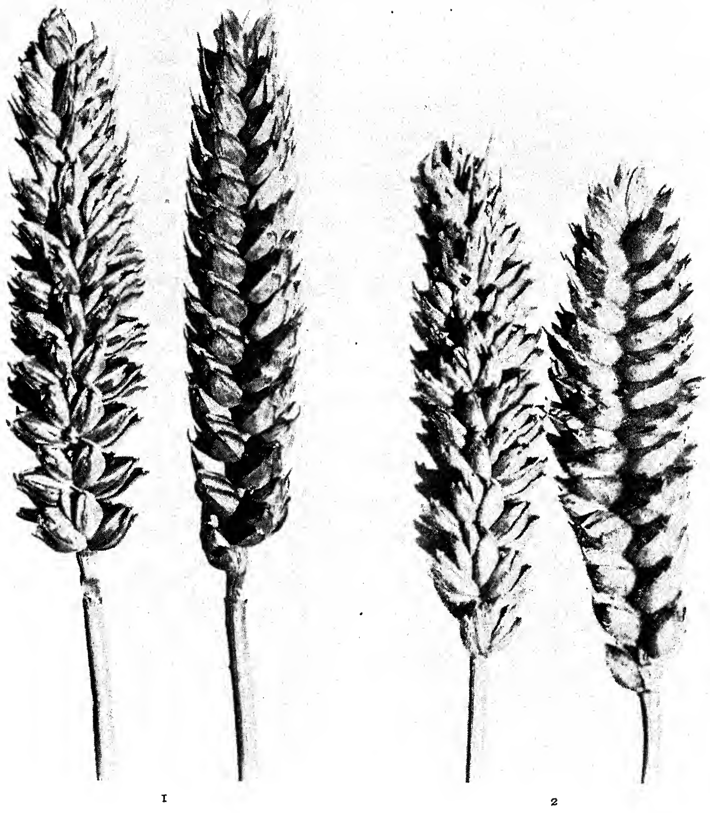


FIG. 190.—BREAD WHEAT (*T. vulgare*, Host).

1. var. *milturum*. (Browick.)

2. var. *anglicum*. (Benefactor.)

CHAPTER XX

CLUB, DWARF, CLUSTER, OR HEDGEHOG WHEAT

T. compactum, Host. *Icon. et descr. Gram. Aust.* iv. 4, t. 7 (1809).
T. vulgare compactum, Alef. *Landw. Fl.* 327 (1866).
T. sativum compactum, Hackel. *Nat. Pfl.* ii. 2, 85 (1887).
T. tenax, A. II., *compactum*, Asch. u. Graeb. *Syn.* ii. 686 (1901).

THE most ancient of wheats possessing grains loosely invested by the chaff and readily separated by threshing belonged to this race, and were widely grown by Neolithic man in many parts of Europe.

A remarkable wheat named by Buschan *T. compactum*, var. *globiforme*, was common in the Neolithic and Bronze periods, being found in many deposits of these ages in Hungary, Germany, Switzerland, Italy, Spain, and Sweden. Only the grains are known; these are small, more or less hemispherical, resembling a miniature coffee-bean in shape, the apex blunt, and furrow well defined; the average dimensions about 4·6 mm. long, 3·4 mm. broad, and 3-3·3 mm. thick. Buschan's wheat appears to resemble the Indian Dwarf wheat *T. sphaerococcum* (see p. 321) rather than *T. compactum*.

More typical examples of *T. compactum*, with small oval or elongated grains 5·5-7 mm. long, 3-4·5 mm. broad, like those of the common forms of the present day, have only been found in the Neolithic and Bronze Age deposits of Switzerland and Northern Italy.

Subsequently its cultivation decreased, its place being largely taken by the larger-grained Bread wheat (*T. vulgare*), which became common in the later prehistoric periods.

There is no evidence that *T. compactum* was known to the ancient Egyptians, Greeks, or Romans.

The small-grained wheat referred to by C. Bauhin in 1623 (*Pinax Theatri botanici*) as *Triticum sylvestre creticum*, and grown extensively at that time in Crete, was doubtless a form of *T. compactum*.

As mentioned later, this wheat is now widely distributed more or less sporadically among the longer-eared wheats, but entire crops of it are rarely seen, a fact which may account for the somewhat remarkable

absence of it from English herbaria of the seventeenth and eighteenth centuries in which representatives of most of the other races of wheat are found.

In this species the ears are very short and dense, with stiff glumes and well-filled spikelets closely packed and arranged almost at right angles to the rachis. In some forms the ears are clubbed, the spikelets being more crowded at the apex than the base, a character met with also in *T. vulgare*.

These wheats are sometimes termed " Cluster " wheats and " Dwarf " wheats, but the latter name is not particularly appropriate since many of the forms possess tall straw.

In France the name " Hérisson " (Hedgehog) is given to them; in Germany the beardless forms are designated " Binkel " wheats, the bearded varieties being known as " Igel " wheats.

Host first gave them specific rank in 1807, and refers to their cultivation in Styria under the name " Binkel."

The closely packed, short, rigid ear is characteristic, but the morphological features of the leaves, culms, glumes, and grain indicate the closest affinity with *T. vulgare*.

When grown from single ears many forms are quite constant; others, more especially those which possess "clubbed ears," *i.e.* dense at the apex and laxer at the base, frequently exhibit extensive segregation, lax, intermediate, and dense-eared forms, bearded and beardless with smooth or pubescent chaff, being often found among their descendants.

The Club wheats are widely distributed at the present day, most frequently mixed with various forms of *T. vulgare* or among *T. durum* in Asiatic Russia; pure crops of them are uncommon except in Central Asia and the Pacific Coast States of North America.

In Asia they are prevalent in Turkestan and the western provinces of the Transcaucasus and more sparingly in Siberia. I have obtained forms also from China and Manchuria.

It is somewhat remarkable that true *T. compactum*, Host, is absent from Persia and India, the examples attributed to this race by Howard belonging to the very distinct race *T. sphaerococcum*, mihi (see p. 321).

In Europe they are met with in South-East Russia, Germany, France, Italy, Switzerland, Spain, and Portugal, and were formerly grown in England under the names " Club," " Cluster," or " Thickset " wheats.

I have also had specimens from Rhodesia, South Africa.

In North America they are cultivated on a somewhat extensive scale in the States of California, Oregon, Washington, and Idaho.

In South America some forms are grown in Chili.

Most of the Club wheats resist frost, drought, and fungi well, and grow freely on the poorer classes of soils; they are chiefly spring forms,

many of them exceptionally early; only a few winter late-ripening forms are known.

The straw is erect and usually stout, not liable to lodge, though a few forms have soft weak stems. The ears are prolific in number of grains, many of the spikelets ripening three or four each; the yield in volume or weight per acre is, however, comparatively low as the grains are individually of small size. The grains are firmly held by the glumes, a character which renders these wheats particularly suited to cultivation in districts where it is the practice to leave the crop on the field for some considerable time before the harvesting operations can be completed.

The grain is soft or of medium hardness, its quality resembling that of the softer varieties of Bread wheat (*T. vulgare*).

General Characters of *T. compactum*, Host.

The coleoptiles are pinkish or colourless.

In the majority of forms the young leaf-blades and shoots are of the erect "spring" habit; a few are semi-erect, others having the prostrate "winter" habit.

The leaves are pale yellowish-green or glaucous blue-green, and the surfaces always more or less hairy, the arrangement of the hairs in most forms resembling that of *T. vulgare* (Fig. 164); a few forms have leaves clothed with soft hairs somewhat similar to those of *T. turgidum* and *T. dicoccum*.

The straws are erect, stiff, and generally hollow, with comparatively thin walls, though one or two kinds have solid straws. They possess five or six internodes above ground, and vary in height from 93 to 140 cm. (35-55 inches).

The ears usually make their appearance from the side of the leaf-sheath and not from the apex as in most wheats. They are short, stiff, and compact, beardless or bearded, from 3·5 to 6 cm. in length, the majority being about 5 cm. (2 inches) long with 17 to 25 closely packed spikelets, the density of the ear being 40-50 or more.

Typical ears are of uniform density and oblong or somewhat oval in outline as viewed from the 2-rowed side; others, especially those of hybrid origin, are "clubbed," the spikelets being crowded towards the apex and loosely arranged at the base. In section the ears are square or more frequently oblong, the width across the imbricated face being usually 10-12 mm., and across the 2-rowed side 13-20 mm.

The rachis is fringed with short hairs along the side and across the upper part of each notch immediately beneath the points of insertion of the spikelets.

The spikelets possess 6-7 flowers, 3-5 of which frequently produce grain; they are 10-13 mm. long, 13-15 mm. broad, and about 3 mm. thick.

The empty glumes are whitish-yellow, red, dark brown or blue-black,

and either glabrous or clothed with soft hairs. Those of the lateral spikelets are 8-9 mm. long, 5- to 6-nerved, and unsymmetrical, measuring from 3 to 4 mm. from the midrib to the outer margin, and 1-1·5 mm. to the inner margin. In beardless varieties the apical tooth of the empty glume is bluntish and from ·5 to 1·5 mm. long ; in bearded varieties it is generally prolonged into a fine awn usually not more than 5 mm. long, though occasionally reaching a length of 3 cm. In most forms the midrib or keel

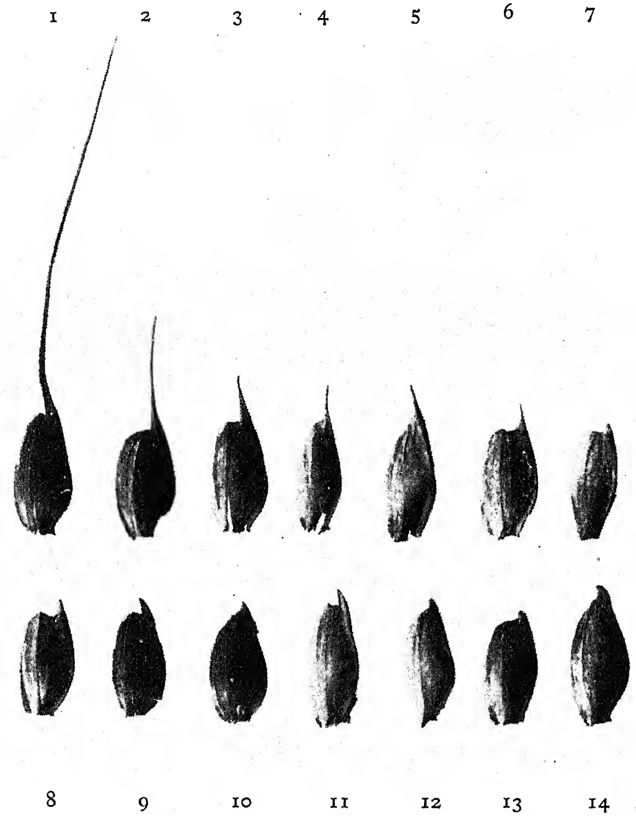


FIG. 191.—Empty glumes of Club wheat (*T. compactum*) (× 2).

is not prominent except in the upper half of the glumes, the basal half of the latter being rounded with only a slight indication of the central nerve ; some Asiatic forms, however, are keeled from the tip to the base. The various forms of empty glume are illustrated in Fig. 191.

The flowering glumes are inflated, about 100 mm. long, 7- to 10-nerved, the parts covered by the empty glume being thin and pale in colour ; in bearded varieties the flowering glumes terminate in scabrid awns 5-9 cm. long, which in some forms diverge widely.

The palea is of the ordinary bicarinate form.

The grains, which are white, yellowish, or red, are small, oval, narrow towards the apex and plump, the cheeks right and left of the shallow furrow usually well filled (Fig. 192). In some forms they possess a prominent dorsal hump similar to that found in *T. turgidum.*

The endosperm in the majority of forms is opaque and starchy, but in some it is flinty.

In well-developed grains the breadth is usually greater than the thickness.

FIG. 192.—Grains of Club wheat (*T. compactum*), front, back, and side views (nat. size).

FIG. 193.—Grains of the spikelets of one side of an ear of Club wheat (*T. compactum*) (nat. size).

Below are given measurements of grains taken from the spikelets near the middle of the ear of twenty-six varieties.

	Length.	Breadth.	Thickness.
	mm.	mm.	mm.
Average	6·19	3·31	3·13
Limits	5·7-7·0	2·9-3·75	2·85-3·65
Ratio	100	53·47	50·46

VARIETIES OF *T. compactum*

I. *Ears bearded*—

1. Glumes white, glabrous.
   - *a.* Grain white . . . . var. *splendens*, Körn.
   - *b.* Grain red . . . . var. *icterinum*, Körn.
2. Glumes white, pubescent.
   - *a.* Grain white . . . . var. *sericeum*, Körn.
   - *b.* Grain red . . . . var. *albiceps*, Körn.
3. Glumes red, glabrous.
   - *a.* Grain white . . . . var. *Fetisowii*, Körn.
   - *b.* Grain red . . . . var. *erinaceum*, Körn.

4. Glumes red, pubescent.
   a. Grain white . . . . var. *rubriceps*, Körn.
   b. Grain red . . . . var. *echinodes*, Körn.
5. Glumes blue-black, glabrous.
   Grain red . . . . var. *atriceps*, Körn.
6. Glumes blue-black, pubescent.
   Grain red . . . . . . var. *atrierinaceum*, Körn.

II. *Ears beardless*—

1. Glumes white, glabrous.
   a. Grain white . . . . var. *Humboldtii*, Körn.
   b. Grain red . . . . . . var. *Wernerianum*, Körn.
2. Glumes white, pubescent.
   a. Grain white . . . . var. *linaza*, Körn.
   b. Grain red . . . . . . var. *Wittmackianum*, Körn.
3. Glumes red, glabrous.
   a. Grain white . . . . var. *rufulum*, Körn.
   b. Grain red . . . . var. *creticum*, Körn.
4. Glumes red, pubescent.
   a. Grain white . . . . var. *crassiceps*, Körn.
   b. Grain red . . . . var. *rubrum*, Körn.
5. Glumes bluish-red, pubescent.
   Grain red . . . . var. *clavatum*, Körn.
6. Glumes black, pubescent.
   Grain red . . . . var. *atrum*, Körn.

Ear bearded ; glumes white, glabrous ; grain white.

T. compactum, var. **splendens**, Körn. *Handb. d. Getr.* i. 53 (1885).
T. vulgare splendens, Alef. *Landw. Fl.* 328 (1866).
T. vulgare, Q., Metzger. *Eur. Cer.* 10 (1824).

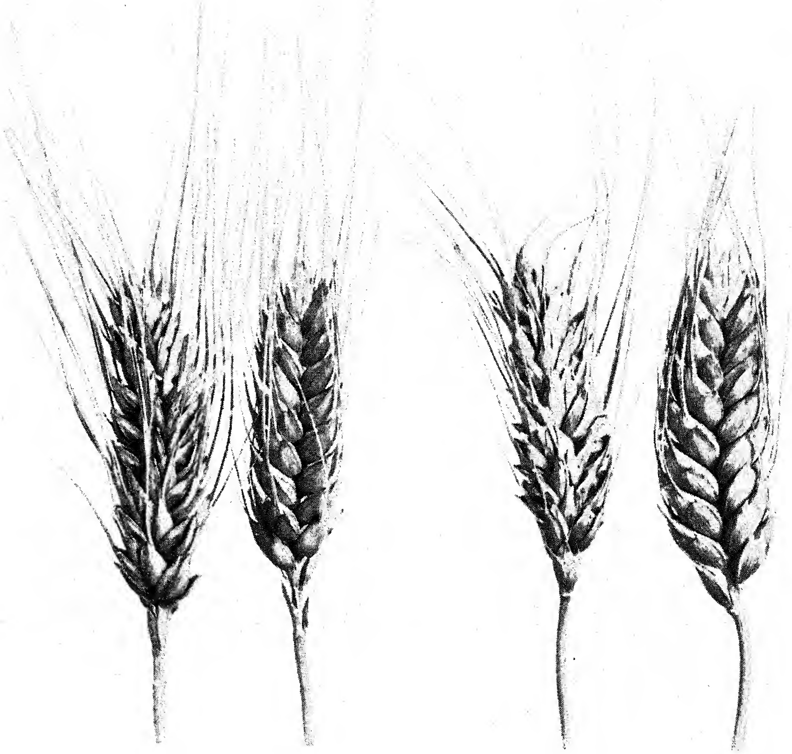
Körnicke received from Chili, under the names **Trigo de la Vuida** and **Trigo Carbillo**, a form of this variety with short thick ears, broader across the side than the face, with straight spreading awns ; he also states that the variety is met in North America and Italy.

Flaksberger records its occurrence in Semiretchensk, Semipalatinsk, and Turkestan.

Ear bearded ; glumes white, glabrous ; grain red.

T. compactum, var. **icterinum**, Körn. *Handb. d. Getr.* i. 53 (1885).
T. vulgare icterinum, Alef. *Landw. Fl.* 328 (1866).
T. vulgare, P., Metzger. *Eur. Cer.* 10 (1824).

One of the most widely distributed varieties of *T. compactum*, forms of it being sent to me from France, Germany, Spain, Rhodesia, Turkey, Asiatic Russia (Bokhara and Semiretchensk), Manchuria, and the United States. Flaksberger mentions its occurrence in Siberia, Turkestan, the Caucasus, Amur, and China, and states that it was formerly found in European Russia.



1 2

FIG. 194.—CLUB WHEAT (*T. compactum*, Host).

1. var. *icterinum*. (Manchuria.)

2. var. *icterinum*. (Central Asia.)

1 2

FIG. 195.—CLUB WHEAT (*T. compactum*, Host).

1. var. *icterinum*. (Semiretchensk.)

2. *erinaceum*. (Heterozygote ?)

1. **Hérisson barbu.**—An early spring form received from France, and from the United States under the name **Walla Walla.**

Vilmorin records its cultivation in the eastern departments of France from Lorraine to Provence. It tillers little, is adapted to spring sowing, and succeeds in cold mountainous districts on poor soils.

Young shoots, erect.

Straw, tall, 135 cm. (53 inches) high, soft, hollow, usually pink when unripe; leaves glaucous.

Ear, 5-6 cm. long, square, 11-12 mm. across sides; spikelets 20-23, often 4- or 5-grained; D=40; awns slender, divergent, 7-9 cm. long (Ear type 1, Fig. 194).

Empty glume, 8 mm. long, apex narrowed with a slender awn ·5-3 cm. long (2, Fig. 191).

Grain, semi-flinty, 6-6·2 mm. long, 3·2-3·5 mm. broad, 3·3-3·5 mm. thick.

2. Early forms similar to (1) but with empty glumes as in 7, 8, Fig. 191, were obtained from Asiatic Russia (Bokhara and Semiretchensk).

3. Winter forms also resembling (1), but later, were obtained from Turkey, Russia, and from a sample of Manchurian wheat.

4. A very dense-eared early form, coming into ear at the end of May at Reading, received from Spain mixed with **Trigo Canuto**, a form of var. *erinaceum* (p. 315).

Young shoots, erect.

Straw, of medium height, 104 cm. (about 41 inches) high, stout, hollow.

Ear, 4·5-5 cm. long, 11-13 mm. across the face, 15 mm. across the side; spikelets 18-19; D=48-50; awns 5-7 cm. long (Ear type 1, Fig. 195).

Empty glume, 8-8·5 mm. long, apex narrow and terminated by a slender awn ·5-3 cm. long (5, Fig. 191).

Grain, flinty, 6·2-6·7 mm. long, 3-3·3 mm. broad, 3·15-3·25 mm. thick.

Ear bearded; glumes white, pubescent; grain white.

T. vulgare sericeum, Alef. *Landw. Fl.* 328 (1866).

T. compactum, var. *sericeum*, Körn. *Handb. d. Getr.* i. 54 (1885).

Körnicke states that this variety is only known in Botanic Gardens; his specimens arose from a cross.

Flaksberger records its occurrence in the Caucasus.

Ear bearded; glumes white, pubescent; grain red.

T. compactum albiceps, Körn. *Handb. d. Getr.* i. 54 (1885).

Körnicke's type was of hybrid origin.

Flaksberger mentions its occurrence in Semiretchensk and Semipalatinsk.

Ear bearded; glumes red, glabrous; grain white.

T. compactum, var. **Fetisowii**, Körn. *Handb. d. Getr.* i. 54 (1885).

Körnicke's type was sent to E. Regel, Petrograd, by Fetisow from Vernoe, Central Asia.

This distinct variety I have only seen from Central Asia, where it appears to be common ; all its forms are early, producing ears at the end of May at Reading.

Flaksberger records its occurrence in Siberia, Turkestan, and S.E. Russia.

Received from Semiretchensk and East Bokhara, Central Asia.

Young shoots, erect.

Straw, of medium height, about 90-100 cm. (36-40 in.) high, hollow, rigid.

Ear, 4·5-5·5 mm. long, 10-12 mm. across the face, 12-15 mm. across the side, usually clubbed at the apex; spikelets 17-19, 4- to 5-grained ; D = 40-50 ; awns brittle, 5-7 cm. long (Ear type 1, Fig. 196).

Empty glume, 8 mm. long, usually narrowed towards the apex, with slender awn 1-3·5 cm. long in the Semiretchensk forms (1, Fig. 191) ; in some forms from Bokhara the empty glume is broader at the apex with a short awn about 4 mm. long (2, Fig. 191).

Grain, flinty, 6·4-6·6 mm. long, 3·3-3·7 mm. broad, and 3·1-3·6 mm. thick.

Ear bearded ; glumes red, glabrous ; grain red.

T. compactum, var. **erinaceum**, Körn. *Handb. d. Getr.* i. 54 (1885).

T. sativum erinaceum, Desv. *From.* 161 (1833).

Körnicke found this variety mixed with var. *Fetisowii* from Central Asia.

Flaksberger records its occurrence in Turkestan, Siberia, Caucasus, Mid- and South-European Russia, and China.

I have received it from Spain, the Transvaal, Manchuria, and as segregates from Chinese wheats and from Hérisson barbu (var. *icterinum*). A glaucous form obtained from a sample of Manchurian wheat ; also among French samples of Hérisson barbu.

Young shoots, prostrate.

Straw, tall, 135 cm. (53 inches) high, somewhat slender, hollow.

Ear, 5-6 cm. long, 10-12 mm. across the face, 12-13 mm. across the side ; spikelets 21-22 ; D = 40-43 ; awns slender, divergent, 7-8 cm. long (Ear types 1, Figs. 194, 195).

Empty glume, 7-8 mm. long, apex narrow with awn ·5-2 cm. long (2-6, Fig. 191). This form has given semi-bearded segregates (2, Fig. 195) with broader empty glumes.

Grain, yellowish-red, mealy or semi-flinty, the flanks of the furrow plump ; 6·1 mm. long, 3 mm. broad, 2·9 mm. thick.

2. An early form with erect young shoots and yellowish-green leaves and ears, found among the progeny of a "clubbed" ear of *T. vulgare* (var. *milturum*) from Chungking, China.

Straw, short, 60-80 cm. (24-30 inches) long ; leaves yellowish-green.

Ear, dense and short, about 4 cm. long, 12 mm. across the face and side ; spikelets 22-24, 4-grained ; D = 48-50 ; awns 5 cm. long (Ear type 1, Fig. 194).

Empty glume, 8 mm. long, keeled to the base, with a curved awn 5 mm. long (2, 3, Fig. 191).

Grain, semi-flinty, often compressed a little on one side ; 2·5 mm. thick, 5 mm. long, 3 mm. wide.

1 2

FIG. 196.—CLUB WHEAT (*T. compactum*, Host).

1. var. *Fetisowi*. 2. var. *Fetisowi*.

(Central Asia.)

1 2

FIG. 197.—CLUB WHEAT (*T. compactum*, Host).

1. var. *echinodes*. 2. var. *echinodes*.

(China.)

Trigo canuto.—A glaucous early form received from Spain mixed with var. *icterinum* (p. 312). A form closely resembling it was received also from Bokhara. They come into ear at the end of May at Reading.

Young shoots, erect.

Straw, of medium height, 102 cm. (40 inches) high, stout, hollow.

Ear, 5-6 cm. long, 12-13 mm. across the face, 13-14 mm. across the side; spikelets 20-22 ; D = 40 ; awns of flowering glumes 5-6 cm. long, stiff, divergent (Ear type 1, Fig. 194).

Empty glume, 7 mm. long, with broad apex; apical tooth acute, 1-2·5 mm. long (6, 8, Fig. 191).

Grain, flinty, apex bluntish with prominent dorsal hump ; 7 mm. long, 3·4 mm. broad, 3·35 mm. thick.

Ear bearded ; glumes red, pubescent ; grain white.

T. compactum rubriceps, Körn. *Handb. d. Getr.* i. 54 (1885).

Körnicke's type was obtained from a cross.

Flaksberger mentions its occurrence in the Caucasus.

Ear bearded ; glumes red, pubescent ; grain red.

T. compactum, var. **echinodes**, Körn. *Handb. d. Getr.* i. 54 (1885).

Körnicke's type was obtained from a cross.

Flaksberger states that it occurs in the Caucasus.

I have received it from China.

An early form obtained among the progeny of a " clubbed " ear of *T. vulgare* (var. *milturum*) from Chungking, China ; the leaves, stems, and ears before ripening are a yellowish grass-green tint.

Young shoots, erect.

Straw, short, 60-80 cm. (24-32 inches) high, stout, hollow.

Ear, 4-4·5 cm. long, sometimes " clubbed," 15 mm. across the face, 20-22 mm. across the side ; spikelets 22 ; D = 50 ; awns stiff, 3·5-4·5 cm. long (Ear types 1, 2, Fig. 197).

Empty glume, 7-8 mm. long, narrow, with slender apical awn 5-8 mm. long (4, 5, Fig. 191).

Grain, flinty or semi-flinty with prominent dorsal hump ; 5·8-6·5 mm. long, 3·1 mm. broad, 3·15 mm. thick.

Ear bearded ; glumes blue-black or dark brown, glabrous ; grain red.

T. compactum, var. **atriceps**, Körn. *Handb. d. Getr.* i. 54 (1885).

Known only to Körnicke from Seringe.

Flaksberger records its occurrence in Semiretchensk and Turkestan, and mentions an unnamed variety with white grain from Turkestan.

The examples I possess originated from an ear of Hérisson barbu (var. *icterinum*) ; the colour of the glumes is not constant.

Young shoots, prostrate.

Straw, tall, 135 cm. (53 inches) high, somewhat slender, hollow, pink when unripe.

Ear, 5-6 cm. long, square, 10-11 mm. across the face and side; spikelets 20; D=40-45; awns divergent, 4-5 cm. long (Ear type 1, Fig. 194).

Empty glume, 7-8 mm. long, narrow; apical tooth curved inwards, acute, 2-4 mm. long (4, 5, Fig. 191).

Grain, flinty, plump; furrow shallow; 6 mm. long, 3·5 mm. broad, 3·1 mm. thick.

Ear bearded; glumes blue-black, pubescent; grain red.

T. compactum, var. **atrierinaceum**, Körn. *Arch. f. Biontologie*, ii. 400 (1908).

Ear, long, strongly awned.

Like var. *atrum* (p. 319), this appears to have been derived from the crossing of a velvet-glumed form of *T. compactum* with *T. turgidum*, var. *iodurum*.

Ear beardless; glumes white, glabrous; grain white.

T. compactum, var. **Humboldtii**, Körn. *Syst. Uebers. Landw. Cer. Poppelsd.* 12 (1873).

Körnicke first obtained this type from a Botanic Garden; later he received specimens from Chili and California.

Flaksberger records its occurrence in the Western Caucasus.

1. A common spring form in samples of **Walla Walla** wheat from the United States.

Young shoots, erect or semi-erect.

Straw, of medium height, 96-104 cm. (38-41 inches) high, stout, striate, hollow.

Ear, 5-6 cm. long, side view somewhat oval, 10-12 mm. across the face, 15-20 mm. across the side; spikelets 23-24; D=46-50 (Ear type 1, Fig. 198).

Empty glume, 7-8 mm. long, apex narrowed; apical tooth blunt, ·5 mm. long (12, 14, Fig. 191).

Grain, semi-flinty, with prominent dorsal hump; 6-6·2 mm. long, 3·25 mm. broad, 3 mm. thick.

2. A spring form from Chili with coarse glumes, glaucous ears of moderate density, approximating to the "Squarehead" forms of *T. vulgare*.

Young shoots, erect.

Straw, of medium height, 104 cm. (30-40 inches) high, stout, hollow with thickish walls.

Ear, 5·7 cm. long, "clubbed," 10-12 mm. across the face, 15 mm. across the side; spikelets 18-22; D=33-36 (Ear type 2, Fig. 198).

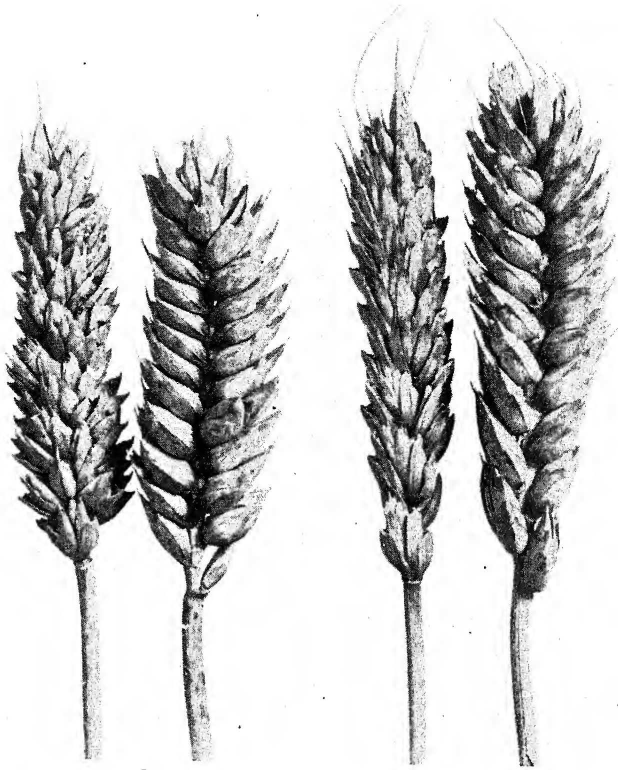
Empty glume, 8-9 mm. long, apex broad; apical tooth blunt, ·5-1 mm. long (14, Fig. 191).

Grain, flinty, 6·6-7 mm. long, 3·3 mm. broad, 3 mm. thick.

3. **Little Club.**—A common glaucous form grown extensively in the Pacific Coast States of America.

Young shoots, semi-erect.

Straw, of medium height, 104 cm. (41 inches) high, hollow.



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2

FIG. 198.—CLUB WHEAT (*T. compactum*, Host).

1. var. *Humboldtii*.
(Walla Walla.)

2. var. *Humboldtii*.
(Chili.)

1 2

FIG. 199.—CLUB WHEAT (*T. compactum*, Host).

1. var. *rufulum*. (Walla Walla.)

2. var. *creticum*. (Mocho de espiga quadrata)

Ear, 4·5-5 cm. long, square, 10-12 mm. across the face and side; spikelets 16-18; D = about 40-45; upper spikelets often with awns 1 cm. long (Ear type 1, Fig. 199).

Empty glume, 8 mm. long, apex narrowed; apical tooth blunt, ·5 mm. long (12, 14, Fig. 191).

Grain, mealy or semi-flinty, 6 mm. long, 3·3 mm. broad, 3 mm. thick.

Ear beardless; glumes white, glabrous; grain red.

T. compactum, var. **Wernerianum**, Körn. *Handb. d. Getr.* i. 57 (1885).

Körnicke obtained forms of this variety from California and Chili.

Flaksberger mentions its occurrence in Kharkov and other parts of Russia, Turkestan, and China.

1. **Kubb.**—A very late glaucous form of winter habit received from Professor Eriksson, Stockholm, and from European Russia.

Young shoots, prostrate.

Straw, of medium height, 114 cm. (45 inches) high, stout, striate, hollow.

Ear, 5 cm. long, 12 mm. across the face, 15-17 mm. across the side; spikelets 24; D = 50 (Ear type 1, Fig. 200).

Empty glume, 7 mm. long, apex narrowed; apical tooth blunt, ·5-1 mm. long (12, Fig. 191).

Grain, flinty, 5·9-6 mm. long, 3·55 mm. broad, 3·25 mm. thick.

2. An early form of this variety, more or less sterile in some seasons and with longer ears than the previous form, was obtained from commercial samples of Chilian wheat.

Ear beardless; glumes white, pubescent; grain white.

T. compactum, var. **linaza**, Körn. *Handb. d. Getr.* i. 52 (1885).

This variety, according to Körnicke, is found in Chili under the name **Trigo linaza**.

According to Werner's description the young leaves are dark green and erect.

Straw, short, 75-85 cm. (about 30-34 inches) high, stiff.

Ear, pale yellow, very dense and short; spikelets 3-grained, 13 mm. across.

Grain, pale yellow, mealy; 6 mm. long, 3·5 mm. broad.

Ear beardless; glumes white, pubescent; grain red.

T. compactum, var. **Wittmackianum**, Körn. *Handb. d. Getr.* i. 53 (1885).

Körnicke's type was obtained from a Botanic Garden.

Velvet Kubb.—A very late glaucous winter form received from Professor Eriksson, Stockholm. Similar but earlier forms also among commercial samples of Walla Walla wheats from the United States, and from Vilmorin, Paris, under the name **Chili velu**.

Young shoots, prostrate.

Straw, tall, 114 cm. (45 inches) high, soft, hollow.

Ear, 5·0-6 cm. long, 12 mm. across the face, 15-17 mm. across the side; spikelets 23-24; D=40-45 (Ear type 1, Fig. 200).

Empty glume, 7-8 mm. long, apex narrowed; apical tooth blunt, 1 mm. long (Form 12, Fig. 191).

Grain, flinty with prominent dorsal hump; 6·2 mm. long, 3·5-3·75 mm. broad, 3·5 mm. thick.

Ear beardless; glumes red, glabrous; grain white.

T. compactum, var. **rufulum**, Körn. *Handb. d. Getr.* i. 52 (1885).

Körnicke's type appears to have been a segregate from a cross.

A glaucous form received in a sample of Walla Walla wheat from the United States.

Young shoots, semi-erect.

Straw, tall, 127 cm. (50 inches) high, hollow.

Ear, 6-6·5 cm. long, tip with a few awns, 10-11 mm. across the face, 12-14 mm. across the side; spikelets 22-25; D=35-40 (Ear type 1, Fig. 199).

Empty glume, 7 mm. long, keeled to the base, apex broad; apical tooth blunt, ·5-1 mm. long (7, Fig. 191).

Grain, semi-flinty, prominent on the dorsal side; 6·9 mm. long, 3·4 mm. broad, 3·5 mm. thick.

Ear beardless; glumes red, glabrous; grain red.

T. compactum, var. **creticum**, Körn. *Handb. d. Getr.* i. 52 (1885).

A widely distributed variety received from France, Germany, Portugal, and China.

Flaksberger records its occurrence in Siberia, Semiretchensk, Turkestan, and the Pamir Plateau.

1. **Hérisson sans barbes.**—A glaucous early form received from France.

Young shoots, semi-erect.

Straw, tall, 132 cm. (52 inches) high, stout, hollow.

Ear, short and very dense, 4-5 cm. long, 12 mm. across the face, 18 mm. across the side; spikelets 23, 4-grained; D=48-54 (Ear type 2, Fig. 201).

Empty glume, 7 mm. long, apex broad; apical tooth blunt, 1 mm. long (9, Fig. 191).

Grain, semi-flinty, 6 mm. long, 3·2 mm. broad, 3·1 mm. thick.

2. A glaucous form cultivated in Madeira under the names **Mocho de espiga quadrata** and **Rapado de espiga quadrata** is similar, but the apex of the empty glume is narrower (14, Fig. 191) and the ear often has a few awns 1-1·5 cm. long at the tip (2, Fig. 199); resembling this also is Blé carré de Sicile from France and Sicilian wheat from Germany.

3. A grass-green early form among the progeny of a "clubbed" ear of *T. vulgare*, var. *milturum*, from Chungking, China; glumes keeled to the base (10, Fig. 191).

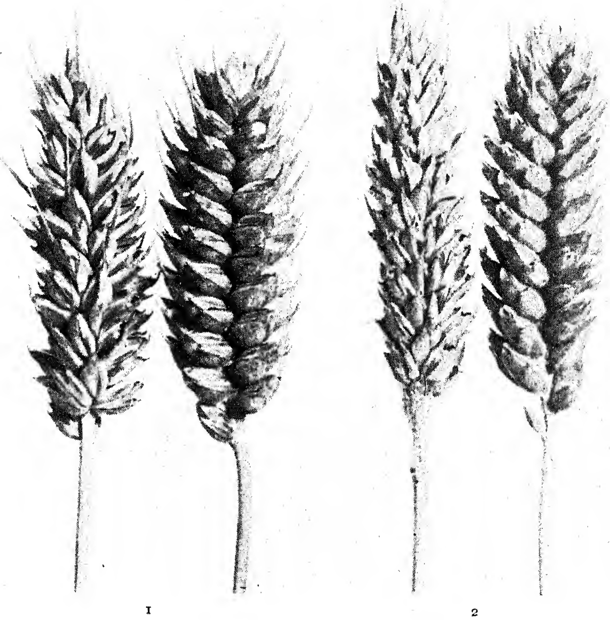
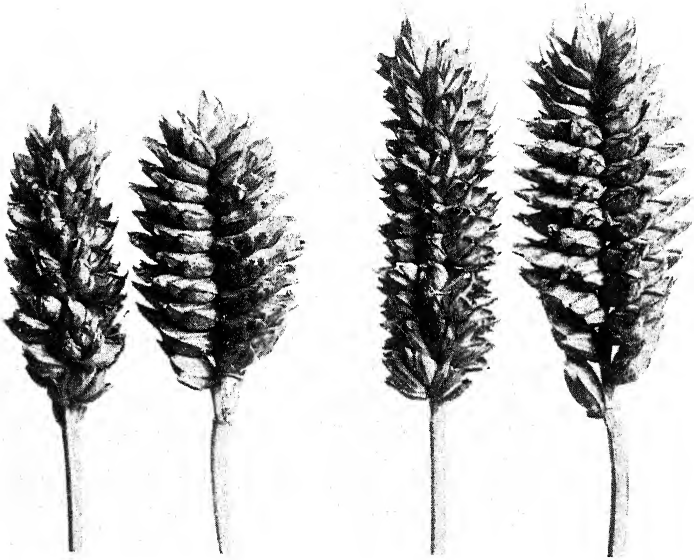


FIG. 200.—CLUB WHEAT (*T. compactum*, Host).

1. var. *crassiceps*. (Walla Walla.) 2. var. *rubrum*.



1 2

FIG. 201.—CLUB WHEAT (*T. compactum*, Host).

1. var. *rubrum*. (China.)

2. var. *creticum*. (Hérisson sans barbes.)

Ear beardless ; glumes red, pubescent ; grain white.

T. compactum, var. **crassiceps**, Körn. *Handb. d. Getr.* i. 53 (1885).

Körnicke's type was of hybrid origin.

I obtained an exceptionally early form of it in a sample of Walla Walla wheat from the United States. Its ears appear about the end of May at Reading and ripen about the last week in July.

Young shoots, erect.

Straw, tall, 130-142 cm. (51-56 inches) high, somewhat slender, hollow. In the early stages of growth the leaves, straw, and ears are of a yellowish grass-green tint.

Ear, 4·5-5 cm. long, square, 12-15 mm. across the face and side ; spikelets 18-20 ; D = 42-45 (Ear type 1, Fig. 200).

Empty glume, 7 mm. long, apical tooth blunt, 1 mm. long (9, Fig. 191)

Grain, flinty, 5·6-5·9 mm. long, 3·2-3·6 mm. broad, 3 mm. thick.

Ear beardless ; glumes red, pubescent ; grain red.

T. compactum, var. **rubrum**, Körn. *Handb. d. Getr.* i. 53 (1885).

A glaucous-eared form received in a sample of Walla Walla wheat from the United States.

Young shoots, prostrate.

Straw, tall, 130 cm. (51 inches) high, stout, hollow, pink when unripe.

Ear, 5-6 cm. long, 12 mm. across the face, 12-15 mm. across the side; spikelets 20-22 ; D = 40-42 (Ear type 2, Fig. 200).

Empty glume, 7 mm. long, narrow at apex; apical tooth blunt, 1 mm. long (9, Fig. 191).

Grain, flinty, 6·2-6·4 mm. long, 3·2-3·6 mm. broad, 3·15 mm. thick.

A short, dense-eared form of this variety with grass-green leaves and ears 4-4·5 cm. long (D = 48-50) was obtained among the progeny of a "clubbed" ear of *T. vulgare* (var. *milturum*) from Chungking, China (2, Fig. 200).

Ear beardless ; glumes bluish-red, pubescent ; grain red.

T. compactum, var. **clavatum**, Körn. *Handb. d. Getr.* i. 53 (1885).

Körnicke states that the type of this variety received by him from Hohenheim has somewhat elongated narrow ears, slightly awned at the tip, with blue-black glumes on a reddish ground like those of *T. turgidum*, var. *dinurum* (p. 257).

Ear beardless ; glumes blue-black, pubescent ; grain red.

T. compactum, var. **atrum**, Körn. *Archiv f. Biontologie*, ii. 398 (1908).

Körnicke's type with more or less quadrangular ears was derived from specimens shown in 1883 in an Agricultural Exhibition by Bestehorn, who crossed various wheats ; this variety was apparently the result of crossing some form of *T. compactum* with *T. turgidum*, var. *iodurum*.

A glaucous form received in a sample of Walla Walla wheat from the United States.

Young shoots, prostrate.

Straw, tall, 118 cm. (47 inches) high, stout, hollow.

Ear, 4·5-5 cm. long, sometimes "clubbed," 12 mm. across the face, 15-17 mm. across the side; spikelets 20-22; D=50 (Ear type 1, Fig. 200).

Empty glume, blue-black, and clothed with pale hairs except near the base, where it is yellowish-white like the unexposed portions of the flowering glume; 7 mm. long; apex narrow; apical tooth curved, blunt, 1 mm. long (9, Fig. 191).

Grain, flinty, 5·7 mm. long, 3 mm. broad, 3·1 mm. thick.

CHAPTER XXI

INDIAN DWARF WHEAT

T. sphaerococcum, mihi.

THIS race, which I received from India and parts of Persia, is referred by Howard to *T. compactum*, Host, but the latter so far as I am aware does not occur in India.

T. sphaerococcum resembles *T. compactum* only in the possession of a short dense ear; the straw, however, is stouter, the leaves shorter, more erect and rigid, and the glumes different in form and texture. The grain also is very small and the typical form is of characteristic hemispherical shape, resembling that of the prehistoric *T. compactum*, var. *globiforme*, of Buschan.

When grown side by side with numerous forms of *T. compactum* from all parts of the world, its specific differences are strikingly evident.

It is cultivated in the Punjab and Central and United Provinces of India, and I obtained examples of it among **Kallak** (= little head) wheat from Persia. Doubtless the same race is referred to by Duthie and Fuller in *Field and Garden Crops of the North-West Provinces of Oudh* (1882) as "a curious round-berried wheat named 'Paighambari,' apparently an introduction from Arabia," but I have been unable to trace its occurrence in the latter country.

This race resists drought well and, according to Howard, is generally grown with inundation moisture and little rain. The Indian examples are resistant to Yellow Rust at Reading.

GENERAL CHARACTERS OF *T. sphaerococcum*, mihi.

The young plants have upright shoots; young leaves as in *T. vulgare*.

At Reading the straw is short, averaging not more than 65-70 cm. (24-28 inches), but in India it sometimes reaches a height of 3 feet or more. It is hollow, very stiff and erect with 4 to 5 internodes, which in some varieties are pinkish. The successive internodes of ten well-grown stems measured from below upwards ·5 cm., 5·2 cm., 13·0 cm., 17·7 cm.,

and 31·5 cm. respectively. Below the ear the straw is frequently bent in a sinuous fashion.

The culm leaf-blades are somewhat rigid, comparatively short, 10-16 cm. long, and 1·2-1·5 cm. broad, tapering quickly towards the tip, their upper surfaces scabrid with a few coarse hairs on the ribs. The auricles are long, narrow, and fringed with a few hairs.

The ears are short, generally measuring 4-6 cm. (about $1\frac{1}{2}$-$2\frac{1}{4}$ inches) in length, with 14 to 20 spikelets ; density usually = 38-42.

Along the edges of the rachis is a fringe of white hairs ·25 to ·5 mm. long, which also extends across the front of the rachis at the base of each spikelet.

1 2 3

FIG. 202.—Empty glumes of Indian Dwarf wheat (*T. sphaerococcum*) (× 2).

FIG. 203.—Grains of Indian Dwarf wheat (*T. sphaerococcum*), front, back, and side views (nat. size).

The spikelets are about 10 mm. long, 10 mm. across, and 4 mm. thick, often with 6 or 7 flowers, 4 or 5 of which may produce grain.

The empty glumes, which have an inflated appearance, are 8-9 mm. long and 4 or 5 mm. across the outer half. They possess 6 or 7 nerves, and are generally keeled in the upper part only, though in some forms the midrib is somewhat prominent below. At the apex is a broad curved scabrid tooth (Fig. 202).

FIG. 204.—Grains of the spikelets of one side of an ear of Indian Dwarf wheat (*T. sphaerococcum*) (nat. size).

The flowering glume is inflated, 9-nerved, and rounded on the back ; in the beardless varieties the tip terminates in a short awn 3 or 4 mm. long, the bearded forms possessing very stiff awns 1·5 to 2 cm. long, which are frequently bent in a sinuous manner near the base and in ripe ears spread outwards irregularly.

The palea is 7-8 mm. long, fringed with hairs along the two keels.

The grains are of very characteristic form, being shorter and rounder than those of other wheats (Figs. 203, 204). They are often somewhat angular and unsymmetrical on account of pressure of the glumes.

FIG. 205.—INDIAN DWARF WHEAT (*T. sphaerococcum*, mihi).

1. var. *echinatum*. 2. var. *rubiginosum*.

The apex is truncate with a short "brush," the furrow shallow.

The grains measure from 4 to 5·5 mm. long, 3-3·7 mm. broad, and 3-3·7 mm. thick; the ratio of length : breadth : thickness = about 100 : 75 : 75.

T. sphaerococcum is a very early wheat, the ear escaping from the upper leaf-sheath about May 20 at Reading.

VARIETIES OF *T. sphaerococcum*, mihi.

Ear bearded—

1. Glumes white, glabrous; grain white . . var. *echinatum*, mihi.
2. Glumes white, glabrous; grain red . . var. *spicatum*, mihi.
3. Glumes red, glabrous; grain red . . . var. *rubiginosum*, mihi.

Ear beardless—

4. Glumes white, glabrous; grain white . . var. *tumidum*, mihi.
5. Glumes white, glabrous; grain red . . var. *rotundatum*, mihi.
6. Glumes white, pubescent; grain white . . var. *globosum*, mihi.

Ear bearded; glumes white, glabrous; grains white.

T. sphaerococcum, var. **echinatum**, mihi.

T. compactum, var. *splendens*, Howard and Howard. *Wheat in India*, 193 (1910).

This variety I received from the United Provinces, India, through H. M. Leake, Esq. It is recorded from the Central Provinces by Howard and Howard.

Young shoots, erect.

Straw, stout, rigid, hollow, very short, at Reading 45-60 cm. (18-24 inches) long.

Ear, erect, stiff, 4·5-6·5 cm. long, almost square, 10-11 mm. across the face and side; spikelets 15-23, 3- to 4-grained; D = 35-40 (Ear type 1, Fig. 205).

Empty glume, 4-6 mm. long, 3·5-4·5 mm. across, with a broad curved scabrid tooth (1, Fig. 202); awns of flowering glumes spreading, stout, rigid, 1-2·3 cm. long, often more or less curved.

Grain, very short, prominent on the dorsal side, flinty; apex blunt, 4-5 mm. long and 3 mm. broad.

Ear bearded; glumes white, glabrous; grain red.

T. sphaerococcum, var. **spicatum**, mihi.

T. compactum, var. *icterinum*, Howard and Howard. *Wheat in India*, 214 (1910).

Mentioned by Howard and Howard as a wheat of the Central Provinces, but not described. I have not seen it.

Ear bearded; glumes red, glabrous; grain red.

T. sphaerococcum, var. **rubiginosum**, mihi.

T. compactum, var. *erinaceum*, Howard and Howard. *Wheat in India*, 178 (1910).

Received from India as "Punjab Type 4" (2, Fig. 205).

In morphology and habit it closely resembles var. *echinatum*, but has dark red glabrous glumes often with a glaucous bloom. The grain is small, pale red, and flinty.

Ear beardless ; glumes white, glabrous ; grain white.

T. sphaerococcum, var. **tumidum**, mihi.

T. compactum, var. *Humboldtii*, Howard and Howard. *Wheat in India*, 179 (1910).

This variety I received from the United Provinces, India, and from the Punjab as "Type 7" (1, Fig. 206).

Young shoots, erect.

Straw, stout, very stiff, hollow, short, and pinkish especially in the upper part, 60-72 cm. (24-28 inches) long at Reading.

Ear, erect, stiff, 4·5-6 cm. long, almost square, 10-12 mm. across the face and side ; spikelets rigid, 15-21, 3- to 4-grained ; D = 32-45.

Empty glume, 7 mm. long, 4·5 mm. broad, with strong curved scabrid tooth (3, Fig. 202).

Grain, small and short, flinty or mealy sometimes, often irregular from pressure of glumes ; 5-5·5 mm. long, 3·3 mm. broad, 3·3 mm. thick.

Ear beardless ; glumes white, glabrous ; grain red.

T. sphaerococcum, var. **rotundatum**, mihi.

T. compactum, var. *Wernerianum*, Howard and Howard. *Wheat in India*, 179 (1910).

Briefly described by Howard and Howard as a Punjab wheat, "Type 6" (2, Fig. 206).

Ears, 4·4 cm. long, sometimes slightly bearded ; D = 39 ; glumes with pinkish tinge and slightly longer curved keel tooth ; grain small, round, pale red, mealy.

Ear beardless ; glumes white, pubescent ; grain white.

T. sphaerococcum, var. **globosum**, mihi.

T. compactum, var. *linaza*, Howard and Howard. *Wheat in India*, 179 (1910).

Received from India as "Punjab Type 5" (3, Fig. 206).

Young shoots, erect.

Straw, short, erect, stiff, often pinkish and wavy beneath the ear ; about 61 cm. (24 inches) long at Reading.

Ear, 5-6 cm. long, almost square, 10-11 mm. across the face and side ; spikelets 13-16, well filled, 3- to 4-grained ; D = about 30.

Empty glume, 6-7 mm. long, 4 mm. broad with strong curved scabrid tooth. (3, Fig. 202).

Grain, very short, dorsal hump prominent, often flattened on one side ; 5 mm. long, 3·5 mm. broad, 3·3 mm. thick.

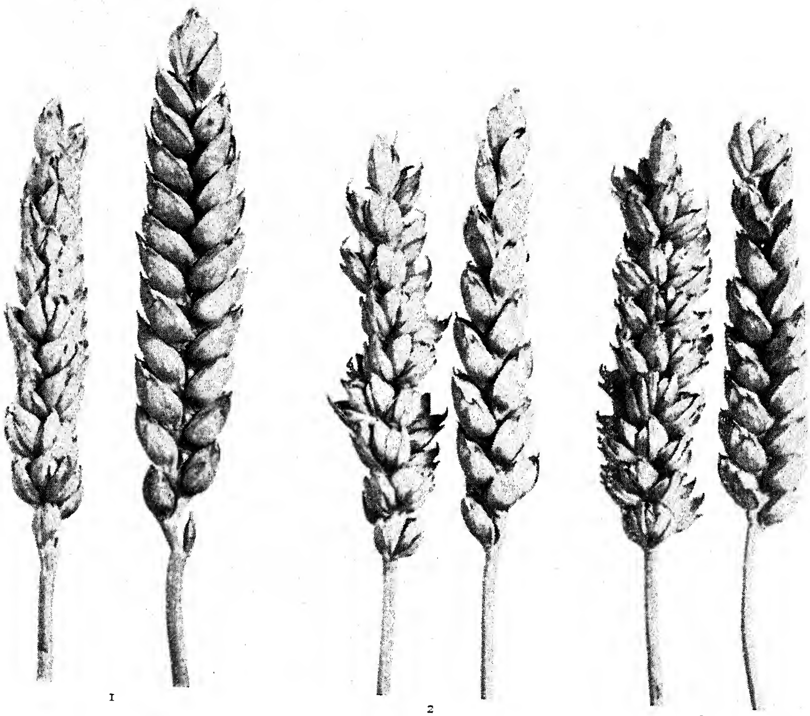


Fig. 206.—Indian Dwarf Wheat (*T. sphaerococcum*, mihi).

1. var. *tumidum*. 2. var. *rotundatum*. 3. var. *globosum*.

CHAPTER XXII

SPELT OR DINKEL

Triticum Spelta, L. *Sp. Pl.* 86 (1753).
Triticum Zea, Host. *Gram. Austr.* iii. 20, t. 29 (1805).
Spelta vulgaris, Seringe. *Cér. eur.* 76 (114) (1841).
Triticum vulgare spelta, Alef. *Landw. Fl.* 334 (1866).
Triticum sativum Spelta, Hackel. *Nat. Pfl.* ii. 81 (1887).

THE word *spelt* in the genitive singular—*speltae*—occurs first in an edict of the Emperor Diocletian (A.D. 301), where it is given as synonymous with the Greek *ὄλυρα*.

According to Hieronymus (A.D. 414), it is of Germanic origin, and was used by the early inhabitants of the province of Pannonia (Hungary) for a cereal which he considered the same as *far* of Latin authors. It is not until the thirteenth century that a distinction is made between *far* and *spelta*; Crescentius, writing then, says that "far resembles spelt, but is larger in the blade and grain" (Cres., lib. iii. cap. de Farre).

There is little doubt that it is much more recent than Emmer (*T. dicoccum*) and Small Spelt (*T. monococcum*), for no remains of it have been found of Neolithic Age and none of Bronze Age, with the exception of a doubtful example mentioned by Heer from the pile-dwellings of the latter period in Switzerland. It is absent from Egyptian tombs, and all the evidence at present available points to the conclusion that it was not known to the ancient Greeks and Romans. I regard it as a segregate of a hybrid between a wheat of the Emmer series (p. 342) and *Aegilops cylindrica* (see p. 343), probably first obtained by the ancestors of the ancient Germanic races who settled in the districts north of the Alps where the cereal is still grown.

At the present time in Italy Emmer is spoken of as *farro* or *grano farro*, Common Spelt as *spelta* or *spelda*.

Of the wheats with a brittle rachis Common Spelt or Dinkel is the race most extensively grown. The greatest area is devoted to this crop in Germany, where in 1901 it was grown on 314,671 hectares (over 777,000 acres), the largest proportion being found in Würtemberg, Bavaria, and

Baden, in which districts it has been cultivated from the earliest times in place of Bread Wheat (*T. vulgare*). On a smaller scale *T. Spelta* is grown in parts of Prussia, Hesse, and Alsace.

In 1900 over 39,000 hectares (96,330 acres) were grown in Switzerland and about 5000 hectares (12,350 acres) in Austria.

It is also cultivated in considerable amount in the northern parts of Spain (Asturias) and on small areas in Switzerland, France, and Italy.

It does not appear to be a farm crop in any other countries of Europe, and I have no authentic record of its occurrence in Africa nor in Persia, India, China, or other parts of Asia.

Spelt will grow wherever Bread Wheat will thrive; it yields best on good wheat land, but will succeed on soils which are too dry and light for the commonly cultivated varieties of *T. vulgare*.

On land not quite suited to it, rye is sometimes mixed with it in the proportion of $\frac{1}{5}$ rye to $\frac{4}{5}$ spelt.

It is one of the hardiest of cereals, being rarely affected by frosts which destroy other wheats, and grows at all elevations, from about 300 to 3000 feet above sea-level in Germany and Switzerland.

Although it is slightly less productive than ordinary wheat and possesses the disadvantage of brittle ears from which the true grain cannot be obtained without special mills, it has advantages which enable it to compete successfully with the more prolific forms of *T. vulgare* in the districts where its cultivation is established. In respect of these advantages its winter hardiness is of the greatest import. Stoll states that after the winter of 1900–1901 38 per cent of the winter wheat of Germany (about 1,800,000 acres) had to be ploughed up in May 1901 on account of the damage done by frost, whereas less than 1 per cent of the Dinkel sown (about 700 acres) was destroyed.

Other points in its favour are its greater resistance to smut, bunt, and rust fungi, and freedom from the attacks of birds. Its straw is stiffer than that of most ordinary wheats and the crop not easily "laid." In addition, it can be harvested sooner than ordinary wheat, and the grain in the ear does not sprout so readily when the reaped crop is left out in wet seasons.

The majority of the kinds of Dinkel are winter forms, though a few less hardy spring varieties are cultivated; Emmer (*T. dicoccum*), however, takes the place of *T. Spelta* where a spring "Spelt" is grown.

The former are sown at the end of September or during the first week of October, while the spring kinds are sown in February and March.

Awned varieties are less frequently cultivated than the beardless forms. Red-chaffed varieties are preferred, as these are hardier than those with white chaff and possess stronger straw.

The viability of the grain is retained longest when it is enclosed in

the glumes and the "Vesen" or husked grain is almost always sown, the germinating capacity of samples of the free caryopses being usually not more than 30 or 40 per cent on account of the bruising sustained in the process of removing them from the husk.

The seed is commonly broadcasted at the rate of 5·5-6·1 hectolitres or 220 to 250 kg. of husked grain per hectare (about 190-220 lbs. per acre), the smaller amount being employed in the case of the spring varieties which tiller well.

It is usually drilled at a depth of $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in rows from 7 to 8 inches apart.

On account of the ease with which the ears break off the straw, the crop is best cut with the sickle before the ears are fully ripe after the straw is white. It is harvested during the first half of August in South Germany. The yield is very variable; in poor mountainous districts it may be as low as 10-15 hectolitres per hectare (about 400-600 lbs. per acre); on better soils it varies from about 40 to 80 hectolitres per hectare (1600-3200 lbs. per acre), the average for Winter Dinkel in a good season being about 40 hectolitres per hectare; for spring-sown Dinkel 25 hectolitres per hectare is a fair crop.

The "Vesen" or pieces of the broken ears obtained by thrashing the crop are subjected to a light grinding process in order to separate the grain from the closely investing glumes, two rough sandstone millstones without the usual grooves being used for the purpose. Where the cultivation of Dinkel is prevalent such mills are common, and the fact that the growth of this cereal does not spread into new districts is attributed to the absence of suitable apparatus for removing the grain from the chaff rather than to the unsuitability of soil or climate.

The grain when ground yields a flour of medium gluten content especially valuable to the confectioner and pastrycook. Some of it is employed in the preparation of farinaceous foods and puddings, a little only being made into bread. A flour suitable for the latter is sometimes made by grinding Dinkel and Bread Wheat grain together.

A considerable amount of Dinkel grain is used in South Germany in soups. When wanted for this purpose the ears are cut from the straw when the grain has just passed the milk-ripe stage; the ears are then dried in an oven and after thrashing are sent to the mill for the removal of the grain from the chaff.

Occasionally the grain in the husk is fed to horses, and the straw, although somewhat stiffer and coarser than that of ordinary wheat, is useful in a chopped state for horses or as long fodder for cattle; the chaff can be fed to cattle also, but it should not be given to horses except in small quantities.

The following comparative composition of (1) Spelt "Vesen" or

grain in the husk as thrashed, (2) the true grains or caryopses, (3) straw, and (4) chaff of Dinkel and Bread Wheat is given by Wolff:

	Water.	Ash.	Crude protein.	Fibre.	N. free extract.	Fat.
Spelt Vesen	14·8	3·7	10·0	16·5	52·3	1·5
Spelt grain	14·5	1·7	13·5	1·5	67·2	1·6
Bread Wheat	14·4	1·7	13·0	3·0	66·4	1·5
Spelt straw	14·3	5·0	2·5	45·0	31·8	1·4
Bread Wheat straw	14·3	5·3	4·5	37·8	36·7	1·4
Spelt chaff	14·3	8·3	3·5	40·0	32·6	1·3
Bread Wheat chaff	14·3	9·2	4·5	36·0	34·6	1·4

The grain has a thinner pericarp than wheat and yields less bran. Spelt flour has less sugar and dextrin and a correspondingly higher starch content than that of Bread Wheat, the nitrogen-content being similar in both cereals.

General Characters of *T. Spelta*, L.

T. Spelta is one of the most distinct of the cultivated wheats, having a characteristic lax ear and a broad truncate empty glume the lateral nerve of which ends in a blunt secondary tooth some distance away from the keel tooth.

The leaves of the young plants of autumn and early spring are dark green, and except in the case of a black-bearded form (var. *coeruleum*) lie close to the ground; they are not much more than about half the width of those of *T. dicoccum* of the same age, being only 3 to 4 mm. across. The older culm leaves, however, are broader than those of *T. dicoccum*. They are comparatively smooth, there being in most varieties only a row of long hairs on the summit and a few smaller ones on the flanks of the longitudinal ridges of the leaves, as in *T. vulgare* (Fig. 164).

The straw is erect, harder and stiffer than that of Bread Wheat, from 100 to 120 cm. (40-48 inches) high and hollow, with thin walls.

The blades of the upper leaves of the straw are from 12 to 20 mm. across, pale greenish-yellow, almost glabrous; the auricles are very large and more or less fringed with long hairs.

The ears are straight or slightly curved, white, red, grey-blue or blue-black, and bearded or beardless, relatively long and lax, the spikelets being generally well separated from each other on the rachis.

They are usually from 10 to 15 cm. (4-6 inches) long, and square or oblong in section. Each ear possesses from 16 to 23 spikelets, the density (D) being 15 to 22.

The notched rachis, which is easily seen between the spikelets, is smooth with more or less hairy margins, the frontal tuft being very small or absent. It is convex on one side, and flat or slightly concave on the other. It is also brittle, breaking into short pieces each 5-6 mm. long, narrow and thin at the base, becoming much thicker and wider at the apex.

The rachis at the point of attachment of each spikelet is broad and often hollow and weak, and when thrashed breaks transversely at this point more easily than at the narrow basal portion of the rachis internode, which is the natural point of disarticulation so clearly seen in the fragile ears of the wild wheats, and the cultivated *T. monococcum* and *T. dicoccum*. In thrashed samples of *T. Spelta* each separate spikelet generally carries with it the internodal portion above its point of insertion, whereas in *T. dicoccum* and other fragile-eared wheats the internode below it is found attached to the thrashed spikelet (Fig. 207).

Although the axis is fragile as

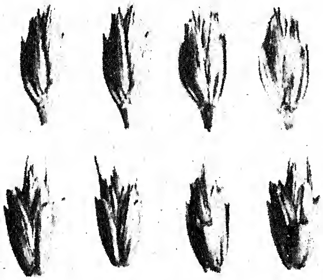
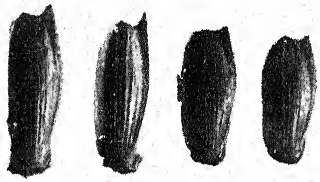


FIG. 207.—Spikelets ("Vesen") of thrashed ears of *T. dicoccum* (upper row) and *T. Spelta* (lower row) (nat. size).



1 2 3 4

FIG. 208.—Empty glumes of Spelt wheat (*T. Spelta*) (× 2).

indicated it resists disarticulation proper, and on this account I include this wheat among the tough-eared races.

The spikelets are oval, convex in section, each consisting of 3 or 4 flowers, two of which generally produce well-developed grains, except in the case of 4 or 5 of the upper spikelets, which often ripen only one grain each; occasionally the central spikelets contain three grains.

The empty glumes are half boat-shaped, with a broad truncate apex and 11 nerves (Fig. 208). The narrow margins are membranous, the broad outer part strong and coriaceous with 6 or 7 nerves, the narrow inner side possessing only 1 or 2. The keel, which is less prominent than in *T. dicoccum*, ends in a short blunt tooth. The strong lateral nerve of the glume ends in a blunt projection, which is always much farther away from the base of the apical tooth than is the corresponding secondary tooth in *T. dicoccum*, *T. turgidum*, or *T. durum*.

The flowering glume is boat-shaped and comparatively thin, with 9-11 nerves and no distinct keel. In some varieties it terminates in a short claw-like projection 2-5 mm. long, in others in a scabrid stiff awn 6-8 cm. long; sometimes the flowering glume of the third imperfect flower bears a short awn 2 cm. long.

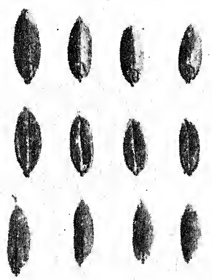


FIG. 209.—Grains of Spelt wheat (*T. Spelta*), front, back, and side views (nat. size).

The palea is about as long as the flowering glume, oval, blunt, and bicarinate, the two keels being fringed with short hairs.

The caryopses, which usually have flinty endosperm, are reddish, long and pointed at both ends, the apex covered with a conspicuous brush of whitish hairs (Figs. 209, 210); they are most firmly enclosed in those ears which are most brittle and have the stoutest glumes. The ventral surface is flattened or hollowed slightly, the furrow of the grain shallow. The cross section is less angular and the breadth proportionately greater than that of a grain of *T. dicoccum*. The caryopses measure 7-10 mm. long, 3-3·5 mm. broad, and 2·7-3 mm. thick; the average ratio of length, breadth, and thickness = 100 : 40·7 : 35·7.

The produce of the thrashed ears, *i.e.* the husked grain or "Vesen," consists of 68 to 79 per cent of caryopses, and 21-32 per cent of chaff (pieces of rachis and glumes), different varieties varying considerably in the relative proportions of grain and chaff.

One hundred caryopses weigh from 5 to 5·8 grams.

The weight of a hectolitre of "Vesen" varies from 40 to 48 kg.

FIG. 210.—Grains of the spikelets of one side of an ear of Spelt wheat (*T. Spelta*) (nat. size).

VARIETIES OF *Triticum Spelta*, L.

I. *Ears bearded*—

1. Glumes white, glabrous	var. *Arduini*, Körn.
2. Glumes white, pubescent	var. *albovelutinum*, Körn.
3. Glumes red, glabrous	var. *vulpinum*, Körn.
4. Glumes red, pubescent	var. *rubrovelutinum*, Körn.
5. Glumes grey-blue, glabrous	var. *Schenkii*, Körn.
6. Glumes blue-black, pubescent	var. *coeruleum*, Körn.

II. *Ear beardless*—

1. Glumes white, glabrous . . . . var. *album*, Körn.
2. Glumes white, pubescent . . . . var. *recens*, Körn.
3. Glumes red, glabrous . . . . var. *Duhamelianum*, Körn.
4. Glumes red, pubescent . . . . . var. *neglectum*, Körn.
5. Glumes grey-blue, glabrous . . . . var. *amissum*, Körn.
6. Glumes grey-blue, pubescent . . . var. *Alefeldii*, Körn.

Ear bearded; glumes white, glabrous.

T. Spelta, var. **Arduini**, Körn. *Handb. d. Getr.* i. 80 (1885).
T. Arduini, Mazz. *Sopra alc. sp. d. frum.* 50, t. iv, Fig. 1 (1807).
T. Spelta, A., Metz. *Eur. Cer.* 26, t. vi, A (1824).
T. Spelta, L., Krause. *Getr.* Heft iv. 13, t. 5, D., E. (1836).
T. vulgare Arduini, Alef. *Landw. Fl.* 335 (1866).

A common variety, rarely pure, but often occurring among other varieties. Winter and Spring forms are met with.

1. **Bearded White Winter Spelt** (1, Fig. 212).—A hardy winter form of moderate yielding capacity, cultivated in Switzerland, South Germany, France, Italy, and Spain.

Young shoots, prostrate.

Straw, tall, 115-130 cm. (about 44-50 inches) high, hollow, thin-walled but firm; leaves glaucous.

Ear, glaucous, lax, 12-15 cm. long, spikelets 18-20, each often bearing 3 grains; D = 15-17.

Empty glume, somewhat thin (2, Fig. 208).

Grain, red, flinty or semi-flinty; 9-10 mm. long, 3·5-4 mm. broad, 3 mm. thick.

2. **Bearded White Spring Spelt.**—A common spring form often grown where the White Winter Spelt is cultivated; its yields are small except on the best soils. The plant tillers well and the straw is very strong and never lodges. It is somewhat shorter than that of the winter form, and the ears ripen 10-12 days later than those of the latter. The ears are very brittle, narrow, and lax, 11-13 cm. long, spikelets 16; D = 13-14; grain 8 mm. long, 3·3 mm. broad, 2·9 mm. thick. Allied to this is a glaucous early form.

Ear bearded; glumes white, pubescent.

T. Spelta, var. **albovelutinum**, Körn. *Handb. d. Getr.* i. 80 (1885).

Körnicke's type was derived from an ear of var. *vulpinum*, which he suggests has been crossed with a velvet-chaffed variety of *T. vulgare*.

Under this variety Werner describes a White, Velvet-chaffed, Winter Spelt with tall straw, 140-150 cm. (55-60 inches) high; ears long, lax, narrow (15-20 cm. long); awns 7-8 cm. long; grains red, mealy, 8 mm. long, 3 mm. broad.

Ear bearded; glume red, glabrous.

T. Spelta, var. **vulpinum**, Körn. *Handb. d. Getr.* i. 80 (1885).
T. spelta, B., Metzger. *Eur. Cer.* 27, t. vi, A. (1824); *Landw. Pfl.* 94 (1841).

T. spelta, L., Krause. *Getr.* Heft iv. 13, t. 5, A., B., C. (1836).
T. vulgare vulpinum, Alef. *Landw. Fl.* 335 (1866).

Metzger states that this variety occurs frequently in fields of var. *Duhameli-anum*, but Alefeld and Körnicke knew it only from Botanic Gardens.

Werner describes two forms of it: (1) **Bearded Red Winter Spelt**, with very tall, hollow, soft straw, 130-150 cm. (52-60 inches) high, liable to lodge and rust. Ears lax and narrow, 12-17 cm. long; spikelets 21; awns 7-8 cm. long; grain long and narrow, 8 mm. long, 3·5 mm. wide.

2. **Bearded Dark Red Winter Spelt** with upright young leaves, straw 110-120 cm. high, narrow ears 12-16 cm. long, and glumes reddish-brown.

Ear bearded; glumes red, pubescent.

T. Spelta, var. **rubrovelutinum**, Körn. *Handb. d. Getr.* i. 80 (1885).

Körnicke's type originated from an ear of var. *vulpinum*. Werner describes one spring and two winter forms of this variety.

The winter forms have bluish-red, velvet-chaffed ears, one with lax, the other with somewhat denser ears.

The summer form (*T. pretiosum*, Jessen h. Dresden, 1872) possesses very long, lax, pale red ears (14-18 cm. long), narrowed towards the apex, spikelets 1 cm. broad, 3-awned, frequently containing 3 long flinty grains, 9 mm. long, 4 mm. broad.

Ear bearded; glumes grey-blue, glabrous.

T. Spelta, var. **Schenkii**, Körn. *Handb. d. Getr.* i. 80 (1885).
T. Spelta, L., Krause. *Getr.* Heft iv. 11, t. 3 and 4 (1836).

Krause mentions this variety and a form of it with greyish-black glumes, *T. Spelta nigrescens*, Schübl.

Körnicke states that he has not seen specimens.

Ear bearded; glumes blue-black, pubescent.

T. Spelta, var. **coeruleum**, Körn. *Handb. d. Getr.* i. 80 (1885).
T. Spelta, C. and D., Metzger. *Eur. Cer.* 27, 28 (1824); *Landw. Pfl.* 95 (1841).
T. vulgare coeruleum, Alef. *Landw. Fl.* 335 (1866).

The colour of the glumes of this variety in hot seasons is blue-black on a reddish ground; in wet years the reddish tint predominates.

Bearded Blue Spelt (2, Fig. 211).—A very late form with prostrate or semi-erect young shoots.

Straw, strong, 100-120 cm. (40-48 inches) high; leaves broad, glaucous.

Ear, lax, 14-18 cm. long, narrowed towards the tip, rachis somewhat tough; spikelets 2-9 mm. broad, often with 3 grains in each; D = 15-16.

Empty glume (3, Fig. 208), blue-black on a red ground, but in dull damp seasons pale-ash grey with a dark line along the margins.

Grain, pale red, flinty, 8·5-9 mm. long, 3·5-4 mm. broad, 3 mm. thick.

Werner mentions a very early spring form with taller straw and shorter ears (11-16 cm. long).

I 2

FIG. 211.—SPELT OR DINKEL (*T. Spelta*, L.).

I. var. *Arduini*. 2. var. *coeruleum*.

Ear beardless; glumes white, glabrous.

T. Spelta, var. **album**, Körn. *Handb. d. Getr.* i. 79 (1885).
T. Spelta, E., Metzger. *Eur. Cer.* 28, t. vi, B. (1824); *Landw. Pfl.* 95 (1841).
T. vulgare album, Alef. *Landw. Fl.* 335 (1866).
T. Spelta, L., Krause. *Getr.* Heft iv. 15, t. 6, A. (1836).

One of the varieties most frequently grown and often found mixed with the red-glumed var. *Duhamelianum*.

The following are common forms of this variety:

1. **Beardless White Winter Spelt** (1, Fig. 212).—A form widely cultivated in South Germany and also met with in Switzerland and Southern France. It requires a warm loam for the best yields.

Young shoots, prostrate with narrow leaves.

Straw, reddish, tall, 120-140 cm. (48-55 inches) high; leaves glaucous.

Ear, narrowed towards the apex, pale yellow, very lax, 14-16 cm. long; spikelets narrow, 2-grained; D = 16.

Empty glume (1, Fig. 208).

Grain, pale, brownish-red, mealy, narrow; 7 mm. long, 3 mm. broad.

2. **Beardless White Spring Spelt.**—*T. vulgare fringillarum* of Alefeld has short pale ears 11-12 cm. long; spikelets 19-20; D = 15.

Grains, red, flinty, 8 mm. long, 3·2 mm. broad, 3 mm. thick. It ripens 10-12 days later than the winter form above.

3. **Schlegel Dinkel** (3, Fig. 212).—A less hardy form than (1), ripening about a week earlier. It tillers well with straw about 100-110 cm. (40-44 inches) high, and somewhat dense, pale yellow ears 10-14 cm. long; D = 20-22. The spikelets are broad, the grain reddish and mealy or semi-flinty, very long and narrow (10 mm. long, 3·5 mm. broad).

4. **Vogeles Dinkel.**—A prolific winter form originally selected in 1836 by A. Münchenmaier, Hengenberg, in the Neckar Valley, Germany. The straw is tall and somewhat weak, 120-130 cm. (48-52 inches) high, ears 12-17 cm. long, of similar density to those of Schlegel Dinkel (D = 20-22); spikelets short, 19-20, 8 mm. broad; grain angular and red; 7 mm. long, 3 mm. broad.

Ear beardless; glumes white, pubescent.

T. Spelta, var. **recens**, Körn. *Handb. d. Getr.* i. 80 (1885).

Körnicke's type was obtained from an ear of var. *vulpinum*.

Probably crossed with a velvet-chaffed variety of *T. vulgare*.

Ear beardless; glumes red, glabrous.

T. Spelta, var. **Duhamelianum**, Körn. *Handb. d. Getr.* i. 74 (1885).
T. Duhamelianum, Mazz. *Sopra alc. sp. d. frum.* 55, t. iv, Fig. 2 (1807).
T. Spelta, F., Metzger. *Eur. Cer.* 29, t. vi, B. (1824); *Landw. Pfl.* 97 (1841).
T. Spelta, L., Krause. *Getr.* Heft iv. 15, Taf. vi, B., C. (1836).
T. vulgare rufum, Alef. *Landw. Fl.* 335 (1866).

The most frequently cultivated variety, grown extensively in Switzerland and South Germany.

The following are the chief forms of it:

1. **Tyrol Dinkel** (2, Fig. 212).—One of the most prolific winter forms of large Spelt.

Young shoots, prostrate or semi-erect; young leaves narrow.

Straw, tall, stout, 120 cm. (about 48 inches) high.

Ear, very lax, 12-15 cm. long, rachis very brittle; spikelets long and narrow, 7 mm. across with stiff glumes; D = 17-18.

Empty glume (4, Fig. 208).

Grain, pale red, semi-flinty, usually not plump; 10 mm. long, 3·5 mm. broad.

2. **Beardless Red Winter Spelt.**—One of the forms of Spelt widely cultivated in South Germany and Switzerland. It is very hardy and yields well.

Straw, tall, strong, 125-130 cm. (about 50-53 inches) high.

Ear, lax, 15-17 cm. long; spikelets long, 9 mm. broad; D = 16.

Grain, pale red, flinty; 8 mm. long, 3·5 mm. broad.

3. **Beardless Red Spring Spelt** is cultivated resembling (2), but with shorter straw.

Ears, 11-12 cm. long; spikelets 17; D = 15.

Grain, 8 mm. long, 3 mm. broad, 2·7 mm. thick.

Ear beardless; glumes red, pubescent.

T. Spelta, var. **neglectum**, Körn. *Handb. d. Getr.* i. 80 (1885).

Körnicke's type was obtained from a Botanic Garden.

Ear beardless; glumes grey-blue, glabrous.

T. Spelta, var. **amissum**, Körn. *Handb. d. Getr.* i. 79 (1885).

T. Spelta, L., Krause. *Getr.* Heft iv. 15, t. 6, D. (1836).

T. vulgare Duhamelianum, Alef. *Landw. Fl.* p. 335 (1866) (not Mazzucato).

A rare variety which Seringe states was much cultivated at the beginning of the nineteenth century in the Canton of Bern, Switzerland.

Ear beardless; glumes grey-blue, pubescent.

T. Spelta, var. **Alefeldii**, Korn. *Handb. d. Getr.* i. 80 (1885).

Körnicke received his type from Hohenheim.

According to Werner a form of it described below is cultivated in Italy.

Young leaves, narrow.

Straw, very tall, 135-145 cm. (about 53-57 inches) high, strong, hollow.

Ear, narrow, 10-15 cm. long; spikelets 16-18; 7-8 mm. wide; D = 20.

Empty glume, pale reddish-blue, in damp seasons grey-blue with a dark line along the margins.

Grain, long, narrow, flinty; 8 mm. long, 3·5 mm. broad.

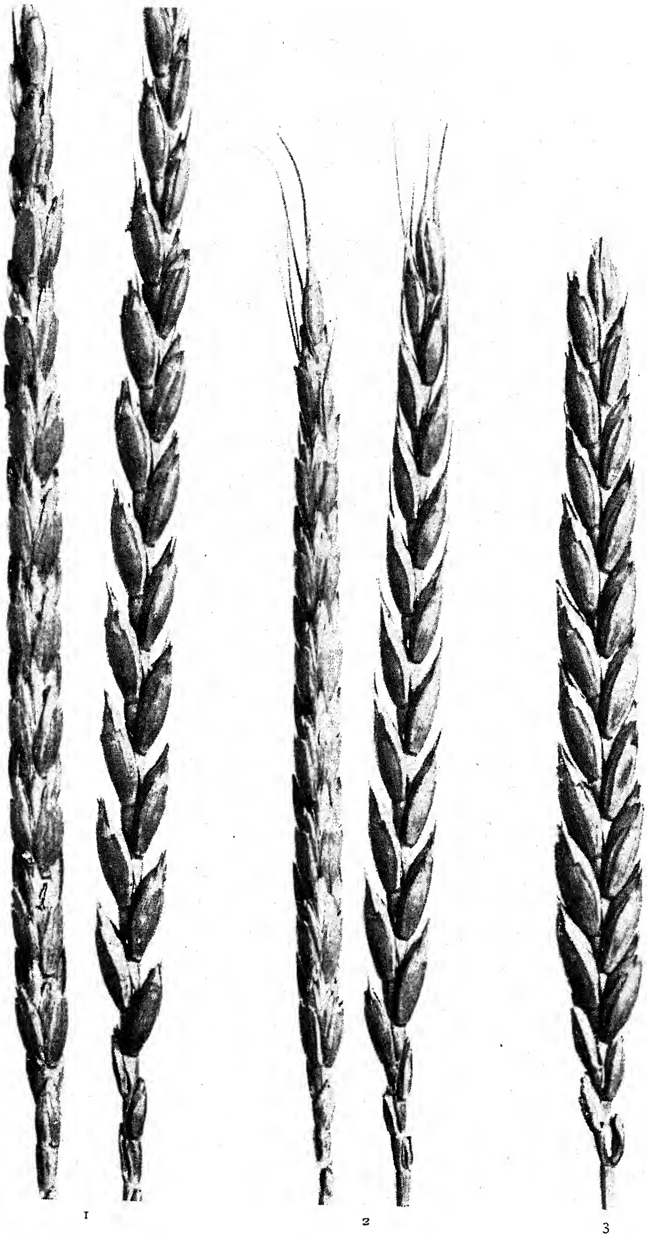


FIG. 212.—SPELT OR DINKEL (*T. Spelta*, L.).

1. var. *album*. (White Winter Spelt.)

2. var. *Duhamelianum*. (Tyrol Dinkel.)

3. var. *album*. (Schlegel Dinkel.)

CHAPTER XXIII

THE ORIGIN AND RELATIONSHIPS OF THE RACES OF WHEAT

ALTHOUGH the cultivation of wheat has not been traced to Paleolithic times, stores of its ears or grain belonging to Neolithic man have been discovered in many parts of Central and Eastern Europe, and the fact that among these are specimens of several kinds suggests that its cultivation even at that period was of considerable antiquity. To the ancient nations of Egypt, Greece, and Rome, the origin of wheat was as much a mystery as it is to-day. The Greeks ascribed the gift of this precious grain to Demeter, whom the Romans identified with their goddess Ceres.

Among the ancient Chinese, wheat was a grant from heaven, and the institution, retained to recent times, of the annual sowing of the five grains—wheat, rice, sorghum, millet, and soy—by the Emperors of China was introduced by the semi-mythical Shen-nung or Chin-nong.

The wild prototypes from which the cultivated wheats have been derived have been diligently sought, and records of their discovery exist in all ages.

According to the legend of Diodorus Siculus (i. 4) the Egyptian goddess Isis discovered " wheat (πυρός) and barley growing promiscuously about the country along with other plants, and unknown to mankind."

The country to which the reference alludes was Nysa, " a high mountain of Phoenicia far away " (Diodorus i. 15), possibly the region of Northern Palestine in which Wild Emmer (*T. dicoccoides*) is found at the present day.

The Chaldean priest Berosus mentions the occurrence of wild wheat (πυρός) in the land of the Babylonians between the Tigris and Euphrates (Syncellus, *Frag. Hist. Graec.* vol. ii. p. 416), and Strabo states that, according to Aristobulus, " a wild corn similar to wheat (πυρός) grows in the land of Musicanus," the " most southern part of India " (Strabo, *Rerum Geog.* lib. xv. t. i. p. 124; t. ii. pp. 776 and 1017, Amstel. 1707).

In more recent times André Michaux in 1787 saw " Spelt " wheat wild in Persia, north of Hamadan (Lamk. *Ency.* ii. 560), and Olivier (*Voy. dans l'emp. othoman*, vol. vi. p. 338, 1807) says that when he was

north-west of Anah on the right bank of the Euphrates " we found near the camp, in a sort of ravine, wheat, barley, and Spelt, which we had already seen many times in Mesopotamia."

From the context these cereals were presumably uncultivated. Since specimens have not been preserved, it is not possible to identify the wheat and " Spelt " to which Olivier refers; it is, however, highly probable that the " Spelt " was the fragile-eared Wild Emmer (*T. dicoccoides*) found at the present day widely distributed throughout Asia Minor as far as the western borders of Persia.

Beijerinck, Hausknecht, and others held the view that all the races of cultivated wheat were derived from the single wild ancestor *T. aegilopoides*, and in the early half of last century Fabre concluded that *Aegilops ovata* was the prototype (see p. 342). The majority of botanists, however, who have studied the problem agree that the wheats are polyphyletic, and that at least two species are concerned in their origin. They are also in accord regarding the main outlines of the relationship of the chief races to each other and to the two wild species *T. aegilopoides* and *T. dicoccoides*.

Schulz arranged the wheats in three separate series, the constitution and relationship of which are indicated in the following table:

Series.	Wild Prototype.	Groups of Cultivated Forms.		
		" Spelt " Grain.	Naked Grain.	
			Normal Ears.	Monstrous Ears.
I. Small Spelt	*T. aegilopoides*	*T. monococcum*	None	None.
II. Emmer .	*T. dicoccoides*	*T. dicoccum*	*T. durum* *T. turgidum*	*T. polonicum*. Not known.
III. Large Spelt or Dinkel	Not known	*T. Spelta*	*T. compactum* *T. vulgare* *T. compactum* × *T. vulgare* = *T. capitatum*	Not known.

Flaksberger's scheme of relationship given on p. 337 also divides the wheats into three similar series or " conspecies," each with its corresponding prototype.

Vavilov discovered that *T. monococcum* is quite immune to *Puccinia triticina*, Eriks., and resistant to *Erysiphe graminis*, D.C. He also found that *T. durum*, *T. polonicum*, and *T. turgidum* constitute a group resistant to these fungi, while *T. Spelta*, *T. vulgare*, and *T. compactum* are all susceptible.

"Conspecies."	*T. monococcum*, L.	*T. eu-dicoccoides*, Flaksb.			*T. speltoides*, Flaksb.		?
Wild forms.	*T. monococcum*, L., *aegilopoides*, Asch. und Graeb. (=*T. aegilopoides*, Bal.)	*T. dicoccum*, Schr., *dicoccoides*, Körn. (=*T. dicoccoides*, Körn.).			Unknown.		?
Cultivated "Spelt" forms.	*T. monococcum*, L., *cereale*, Asch. und Graeb. (=*T. monococcum*, L.)	*T. dicoccum*, Schr., *sementivum*, Flaksb.			*T. Spelta*, L.		?
Cultivated Naked-grain forms.	Unknown.	*T. durum*, Desf.	*T. polonicum*, L.	*T. turgidum*, L.	*T. vulgare*, Vill.	*T. compactum*, Host.	
		T. compactum, Host. (Abyssinian Club Wheats).	*T. Polonicum*, L.	*T. turgidum*, L.	*T. compactum*, Host. (Ordinary Club Wheats).	(Abyssinian Club Wheats.)	*T. polonicum*, L.

The dotted lines indicate dubious relationships.

T. dicoccum has both immune and susceptible varieties. At Reading the Indo-Abyssinian Emmers are slightly susceptible to rusts, the Russian and Serbian forms more resistant, the late-ripening European representatives being immune.

From a study of "serum" reactions Zade placed *T. dicoccum*, *T. durum*, *T. polonicum* in one class, *T. vulgare*, *T. compactum*, and *T. Spelta* in another, *T. monococcum* being distinct from these, and the results of Sakamura's investigations into the chromosome number of the several races suggests a similar grouping.

There is, I think, no doubt that the classification of the races of wheat into (1) Small Spelt, (2) Emmer, and (3) Dinkel or Bread Wheat series, supported as it is by so many independent lines of research, indicates in a broad way their genetic affinities.

In regard to the phylogenetic relationship of the several races of wheat, my investigations have led me to formulate the scheme given on p. 339.

So far as concerns the races which are included in the three series and the prototypes of two of them, it is in substantial agreement with the conclusions of Schulz, Flaksberger, and others; it differs, however, in the view taken of the origin and relationship of the Bread Wheat series.

The evidence upon which the scheme is based is discussed later.

Series I.—The Small Spelt series includes the wild *T. aegilopoides*, Bal., and the cultivated *T. monococcum*, L.

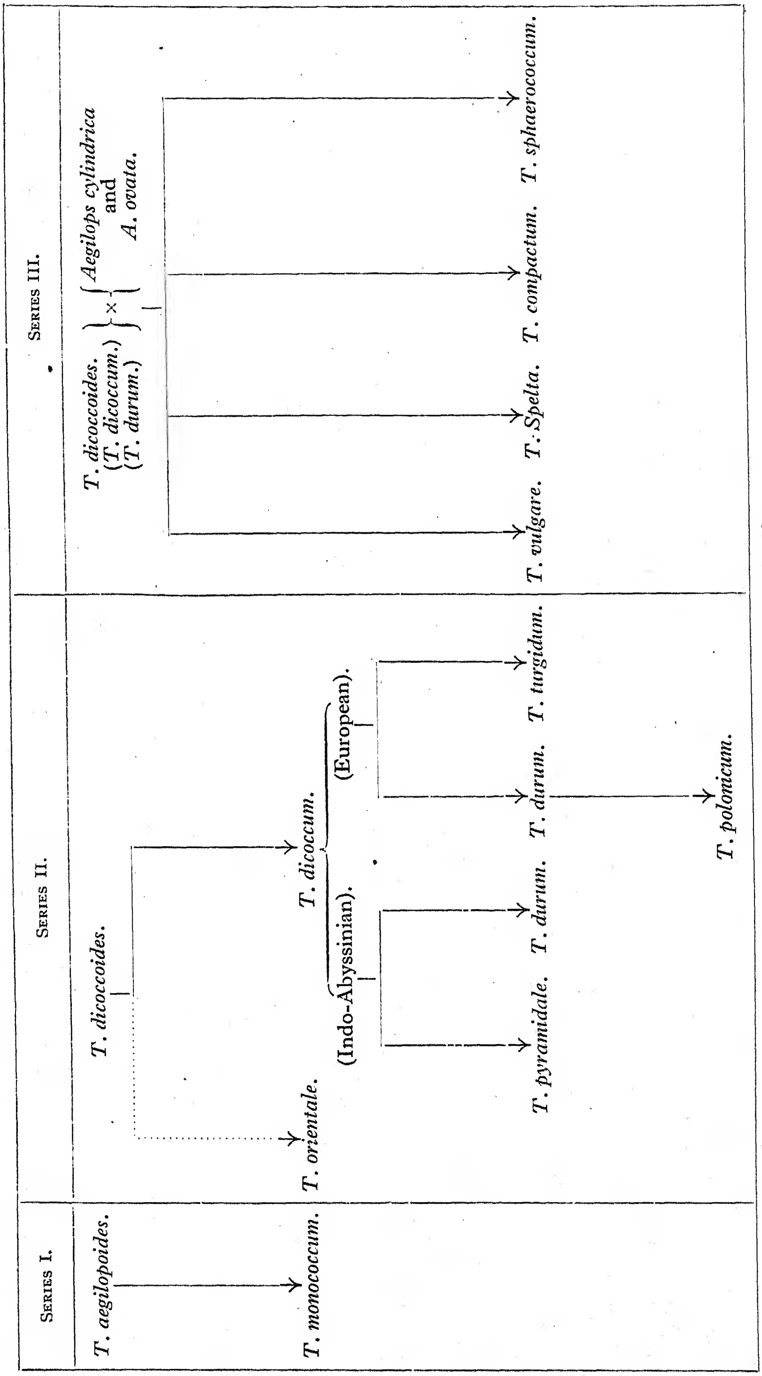
Even from a cursory glance at the mature plants the relationship between the wild *T. aegilopoides* and the cultivated *T. monococcum* is evident.

In all morphological characters of the culm, ear, glumes, and grain there is little or no difference between the two, the only modification being a reduction in the hairs on the leaves and rachis.

Hybrids of *T. monococcum* with wheats of the *dicoccum* and *vulgare* series are quite sterile, and the results of the determination of the chromosome number, immunity to rusts, and the "serum" reactions strikingly support the conclusion that this series is distinct from the rest of the cultivated wheats.

Series II.—The Emmer series comprises the Wild Emmer (*T. hermonis*, Cook) and the cultivated Emmer, Khorasan, Macaroni, Polish, Rivet, and Egyptian Cone wheats.

The Cultivated Emmer Wheats (*T. dicoccum*, Schübl.) constitute an ancient race agreeing closely in almost all its characters with the wild *T. dicoccoides*. In both, the hairs on the surface of the leaf-blades are similar in form, length, and arrangement; the ears also are flat, with



The dotted line indicates dubious relationship.

narrow spikelets containing two grains, and the empty glumes alike in shape and texture. The wild plant has longer grains, and the conspicuous fringe of silky hairs on the margins of the rachis is missing or much reduced in the cultivated race.

The fragile-eared Indo-Abyssinian forms exhibit the closest resemblance to the prototype, possessing, like the latter, easily disarticulated ears, short culms, yellow-green foliage, and the remarkable anatomical character of four to six vascular bundles in the coleoptile, as well as the early habit.

The European Emmers are a taller, later-ripening mutation, with glaucous leaves, the usual pair of vascular bundles in the coleoptile, and a fragile rachis.

Khorasan Wheat (*T. orientale*, mihi) is a small race having pubescent leaves, short almost solid culms, very lax ears, strong awns, long flinty grain, and early habit, all of which characters are found in *T. dicoccoides*, from which I consider it has originated.

The Macaroni Wheats (*T. durum*, Desf.) exhibit obvious affinities with *T. dicoccoides* and *T. dicoccum*, and I regard them as mutations derived in some instances directly from the wild species, in others indirectly from the latter by way of the cultivated Emmers. Like these the Macaroni wheats possess solid culms, erect rigid ears with regularly arranged spikelets, long, narrow, keeled glumes, and narrow, pointed grain ; many forms also have a somewhat fragile rachis.

The Indian examples of the race, particularly the Kathias of the United Provinces, with their comparatively small ears and slightly hairy leaf-blades, appear to have arisen from the Indo-Abyssinian group of Emmers, the European *durums*, with their large, coarse ears, glabrous leaves, and smooth-based awns, being derived from the large-eared, tall-strawed European Emmers.

Polish Wheat (*T. polonicum*, L.), the most recent of the races of wheat, I have no doubt is a mutation of *T. durum*, as first suggested in 1884 by Beijerinck. Like *T. durum*, its leaves are glabrous, its straw tall, striate and almost solid, and the grain long and flinty. Both are also similar in habit, tillering capacity, and resistance to rusts. The only point of difference, namely the excessively long, thin glumes, I regard as a hereditary teratological variation. I have seen occasional specimens of Indian *durums* with elongated glumes suggestive of incipient *polonicum*, and Körnicke states that Schweinfurth sent him from Upper Egypt a transition form between *durum* and *polonicum*.

The lax ear, long spikelet, glumes, and grain of Khorasan wheat (Race III.) suggest a variation towards the production of a *polonicum* from the pubescent-leaved *dicoccoides* or Indo-Abyssinian *dicoccum*.

THE RIVET OR CONE WHEATS (*T. turgidum*, L.) have the characters of a hybrid race produced probably within historic time by the crossing of the tall European *T. dicoccum* with *T. compactum* or a dense-eared form of *T. vulgare*.

Its affinity with the European Emmer can be traced in its morphological characters and habit. The two races agree in the characteristic pubescence of their young leaves. Both have tall, solid or nearly solid culms, and ears with spikelets very regularly arranged along the rachis. They tiller very little and have a similar late-ripening period.

Moreover, the tendency to produce branched ears is strongly evident in these two races and rare in others.

The square ear of *T. turgidum*, its many-flowered spikelets, and plump, blunt-ended grain are characters derived from the dense-eared *compactum* or *vulgare* parent, the dorsal hump of the grain being derived from the Emmer parent.

In its typical form the Rivet race is endemic only in the area in which *T. dicoccum* and *T. compactum* are present, namely, along the northern side of the Mediterranean from Portugal eastward to the Caucasus, where it is found sporadically distributed and hardly typical. It is absent from Asia Minor, Persia, India, and China, in which countries either one or both of the presumed parents are missing.

The solitary case from Baluchistan reported by Howard requires further investigation. Forms bearing some resemblance to *T. turgidum* I have received from the Central Provinces and Bombay; those, of which "Bansi" of Hoshangabad is a good example, are only endemic in the provinces where *T. dicoccum* is grown and are probably hybrids of this race with *T. durum*.

EGYPTIAN CONE WHEAT (*T. pyramidale*, mihi) is a small but distinct race confined to Egypt and Abyssinia. I regard it as an endemic dense-eared mutation derived from the Abyssinian form of *T. dicoccum*. It exactly agrees with the latter in the pubescence of its young leaves, yellow-green culm-leaves, short culms, very early habit, and the shape of its grain, and only differs from it in having short, dense ears with a tough rachis.

SERIES III.—The Bread Wheat series includes Bread Wheat, Dinkel or Large Spelt, Club and Indian Dwarf wheats.

THE BREAD WHEATS (*T. vulgare*, Host).—It is in regard to the origin and relationship of the members of this series that the greatest diversity of view is found among those who have studied the subject. The search for a prototype possessing the characters of the *vulgare* race has been diligently pursued from the earliest times, but nothing approximately like it has been found growing wild. That another primitive species,

distinct from the prototypes of the Small Spelt and Emmer series, is needed to account for the differentiating characters of the Bread Wheat series is, however, generally recognised.

The discovery by Fabre of peculiar plants arising from the ears of the wild grass *Aegilops ovata,* which became gradually transformed in successive generations into wheat indistinguishable from that ordinarily cultivated, led him to conclude that the wheats have been derived by cultivation and selection from this wild species of grass. Fabre's view was shared by many eminent botanists of last century.

In 1889 Körnicke announced that in the wild *T. dicoccoides* he had found the prototype of his *T. vulgare*, which included all cultivated wheats except *T. monococcum*.

Solms-Laubach decided that the ancestral wild wheat is extinct and only the cultivated forms descended from it exist at the present day.

The belief that *T. Spelta* represents an ancestral type, and that the rest of the *vulgare* series have been developed from it, has been somewhat generally accepted, and in the phylogenetic schemes of Schulz and Flaksberger it is placed in the position of a primitive form whose wild prototype is yet undiscovered, although Schulz believes it probably exists in the mountainous parts of the Euphrates-Tigris region.

From a study of the rachis and glumes of the two plants, Stapf states that he is "almost convinced" that *Aegilops cylindrica*, a wild species indigenous in Eastern Europe and Asia Minor, is the prototype of *T. Spelta*.

While the characters of the wheat of the Small Spelt and Emmer series can be traced with reasonable certainty to their respective prototypes, from which they appear to have been derived chiefly by mutation, selection, and cultivation, investigation of the morphological features of practically all known forms of *T. vulgare* has convinced me that there is not, nor has there ever been, a prototype of the Bread Wheat series. The characters of *T. vulgare* and its allies appear to me to be those of a vast hybrid race, initiated long ago by the crossing of wheats of the Emmer series with species of *Aegilops*, and that *T. Spelta* is a segregate of this hybrid.

Crossing between mutants of the same specific prototype is, I think, sufficient to account for many, if not all, of the moderate number of forms found among the races of the Emmer series, but the extraordinary complexity and almost endless number of varieties and intermediate forms of the *vulgare* race can only be satisfactorily explained by the assumption of its hybrid origin from two or more distinct species.

There is scarcely a single character, morphological or physiological, which is not subject to very wide variation, and in respect of any pair of its contrasting characters, such as lax and dense, bearded and beardless ears, different forms of empty glume, early and late ripening period,

prostrate and erect habit of its young shoots, flinty and mealy grains, immunity and susceptibility to attacks of fungi and other features, there exists an almost continuous series of transition forms between their extreme limits.

Any interpretation of the origin of the *vulgare* race and with it the rest of the Bread Wheat series must account for the racial characters mentioned below, which differentiate *T. vulgare* from the Emmer series.

(i.) The presence of a single line of long hairs on the summit of the longitudinal ridges of the young leaf-blades, with shorter ones or none at all on the sides of the ridges.

(ii.) Thin-walled, hollow culms.

(iii.) The exceptionally tough, non-disarticulating rachis.

(iv.) The rounded back and absence of keel on the lower part of the empty glume of a large proportion of the race.

(v.) The comparatively short awns of the fully bearded ears, and the occurrence of beardless and semi-bearded ears.

The presumed prototypes of the Emmers possess none of these; they are, however, all found in *Aegilops ovata*, L., or *A. cylindrica*, Host, and I have no doubt that both these species have entered into the constitution of the *vulgare* race of wheats.

The species named are wild annual grasses, the former widely distributed in the Mediterranean region from Portugal to Egypt, Syria and Transcaucasia, the latter appearing in Italy, the Balkans, South Russia, and Asia Minor. As already indicated, the long hairs on their leaf-blades are like those of *T. vulgare* in form and arrangement but longer. The culms are hollow and thin-walled. The rachis is non-fragile, but the ear falls off the straw as a whole without disarticulating into separate spikelets. The grains are small, resembling in form and general mealiness those of *T. vulgare*, and like the latter are convex on the dorsal side without the prominent ridge found on grains of the Emmer series.

In *A. ovata* the culms are 20-35 cm. high and the ears 2-3 cm. long, with 2-5 spikelets, one or two at the base and apex being rudimentary and sterile. The fertile spikelets are 3- to 4-flowered, each ripening one or two grains.

The empty glumes are convex, inflated, and truncate at the apex, without a keel, but having several prominent lateral nerves, and terminating generally in three or four awns, 2-4 cm. long (1, Fig. 223). The flowering glumes terminate in 2 or 3 short awns, usually less than 2 cm. long.

A. cylindrica is a taller species with more erect culms 30-60 cm. high, and longer, more slender, cylindrical ears 6-12 cm. long, and composed of 5-10 spikelets (Fig. 223). The axis breaks below the spikelets as in *T. Spelta* when roughly handled (Figs. 214, 217). The empty glume

of the lateral spikelet is oblong, broad and truncate at the apex, with a short terminal awn of variable length, and a much shorter lateral tooth, that of the terminal spikelet bearing one or two very long awns. The flowering glumes are awnless or only shortly bearded.

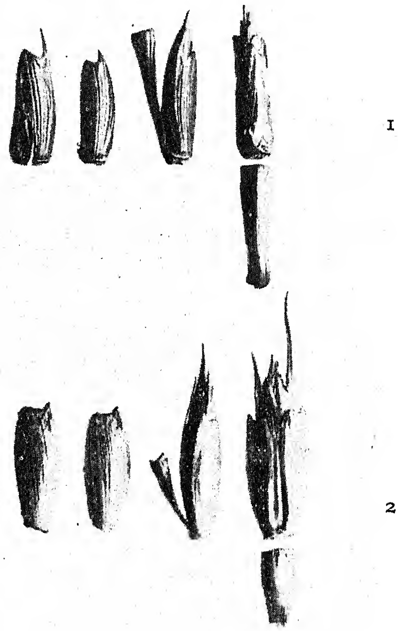


FIG. 214.—Empty glumes and spikelets of (1) *Aegilops cylindrica* and (2) *T. Spelta*, illustrating mode of fracture of the rachis (×2).

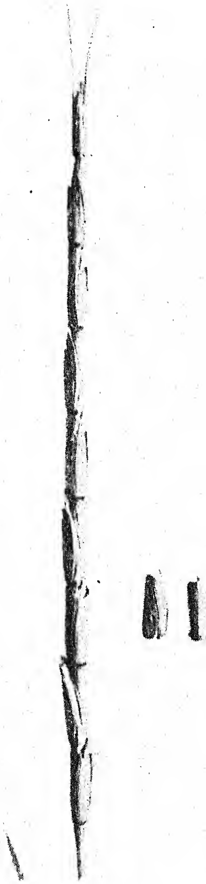


FIG. 213.—Ear of *Aegilops cylindrica*, with two empty glumes (nat. size).

It is conceivable that the heterogeneous race of *T. vulgare* wheats with its numerous *Aegilops* characters may have arisen from the hybridisation of these two species, or from one, or both, by mutation, selection, and cultivation, but I think this is much less possible than the view I have just expressed. The greater length of ear, frequently keeled empty glume, larger grain, and occasional solid culm appear to me to need the introduction of another species like that of *T. dicoccoides* and its derivatives.

Both species of *Aegilops* mentioned have been artificially hybridised with Emmers or with *T. vulgare*. Cook also refers to a Syrian specimen,

intermediate in its ear characters between *A. ovata* and *T. dicoccoides*, which Aaronsohn considered a natural hybrid, and the photographs of the spikelets undoubtedly support this conclusion.

It is highly probable that such natural hybrids are not infrequent, and although the F_1 generation produced and grown under European experimental conditions is generally sterile, the *vulgare* hybrid is fertile with *vulgare* pollen. It is also possible that the natural hybrids between the wild *Aegilops* and the Emmer prototype—the suggested parents of the *vulgare* race—are more fertile under their native climatic conditions than in Central or Western Europe.

The particular contribution made by the two species of *Aegilops* to the *vulgare* race can at present only be surmised. Either of them would account for the keelless empty glume, but the beardless character of half of these wheats has most likely come from the short-awned beardless *A. cylindrica*.

Many forms of *T. vulgare* are glaucous, others are non-glaucous and a green or a yellowish-green tint; the former agree with *A. ovata*, the latter with its sub-species *A. triaristata*, which differs from the type *ovata* chiefly in its colour, more robust growth, and the possession of three instead of four awns on the empty glume.

Empty glumes with a single long terminal awn instead of the usual short apical tooth are not infrequent among *vulgare* and *compactum* wheats (Figs. 165, 191), especially those from Central Asia. This character I regard as evidence of the presence of *Aegilops* in these races, for it appears in hybrids of *A. ovata* with *T. vulgare*, though neither of the parents show it. The three or four long awns on the empty glume of *A. ovata* are reduced to one in the second or third generation of the cross (p. 382 and Fig. 223).

DINKEL OR SPELT (*T. Spelta*, L.).—That *T. Spelta* is in some way closely related to the Bread wheats (*T. vulgare*) is usually admitted. The characteristic arrangement and form of hairs on the young leaves, the hollow culms and broad but slightly keeled empty glumes which they have in common are evidences of their affinity.

Speltoid mutations and transitional speltoid forms are not uncommonly seen, more especially among the *vulgare* wheats coming from Central Asia, Argentina, and Spain.

T. Spelta is frequently grouped with the fragile-eared Emmers, but this classification is based on imperfect knowledge of the nature of its rachis. In *T. dicoccoides* the ear falls in pieces as it ripens (cf. Fig. 77), the rachis disarticulating at the nodes, and a similar though less easy disarticulation is found in the brittle-eared forms of *T. dicoccum*. The rachis of *T. Spelta* is also brittle, and when roughly treated breaks into short lengths, but the transverse fracture occurs below the point of

insertion of the spikelets and not at the exact nodal point; indeed, disarticulation at the node is not always easy to effect, even when force is used, and on this account *T. Spelta* should be included among the tough-eared wheats.

Exactly the same mode of fracture and at the same point of the rachis is found in *Aegilops cylindrica*, and Stapf's conviction that these two are closely related is, I think, undoubtedly correct. My view, however, differs somewhat from his in that I regard *A. cylindrica* not as the prototype of *T. Spelta* but as one of its parents.

The experiments of Fabre, Godron, and others with *Aegilops* × *T. vulgare* hybrids have shown that the complete or even approximate segregation of an *Aegilops* never occurs in any succeeding generation of their descendants, a result almost unique and hitherto unexplained.

T. Spelta, however, which very frequently appears among the progeny of hybrids of *vulgare* wheats with other races, I regard as a segregate nearest to the *cylindrica* parent.

Club Wheat (*T. compactum*, Host).—In the chief morphological characters of its young leaves, culms, glumes, and naked grain this race resembles *T. vulgare*, and there is little doubt that both have had a common origin. The great density of the ears of the race is a characteristic hereditary feature, and such constant, dense, dwarf-eared forms frequently arise apparently *de novo* among the progeny of hybrids between widely different wheats with longer lax ears. I think it highly probable that the *compactum* race arose in this way and made its appearance contemporaneously with the *vulgare* wheats.

It is one of the most ancient of races, archaeological evidence showing that it was widely distributed in prehistoric times, and apparently more commonly cultivated at first than the larger-grained *vulgare* wheats.

Indian Dwarf Wheats (*T. sphaerococcum*, mihi).—Like its ally *T. compactum*, this race probably arose as a mutant among the progeny of an early hybrid. Its peculiar small round grains very closely agree in form and size with Buschan's *T. compactum globiforme*, the naked-grained wheat most commonly grown in various parts of Europe in Neolithic times, and it is possible that the race now confined to India is a remnant of an ancient stock.

CHAPTER XXIV

VARIATION

ONE of the most obvious peculiarities of living things is their variability. No two human beings are alike in all their features, and no two plants of the many thousands present in a field of wheat are exactly alike in all their characters, even where the entire crop has descended from a single ancestral grain.

The form, size, and colour of the glumes, the height, strength, and diameter of the straw, the length, weight, and number of spikelets of the ear, and all other characters of the plant, morphological and physiological, are subject to variation.

Although variations may be classified and investigated from many points of view, they fall naturally into two distinct groups, namely:

(1) *Fluctuations*, or *racial* variations, and
(2) *Discontinuous* variations or *sports*.

FLUCTUATIONS

Fluctuations pass by regular gradation from a lower to an upper limit, and are distributed at random among the individuals forming a crop. When measured, weighed, or counted, the results can be plotted on frequency curves, which conform to the laws of chance.

Variations of this class are produced by changes in the environment of the plant; they belong to the individual and are not inherited.

Examples of fluctuating variability are the lengths and numbers of the spikelets of the ears of a crop of wheat.

Of 500 ears taken at random from a field of "Swan" wheat, the length varied between 50 and 110 mm. Measured and arranged in groups differing from each other by 5 mm. the frequencies or numbers of individuals in each class were—

LENGTHS OF THE EARS (mm.)

Class	50/54	55/59	60/64	65/69	70/74	75/79	80/84	85/89	90/94	95/99	100/104	105/109
Frequency	1	9	28	30	93	94	98	77	49	10	9	2
Percentage in each class	·2	1·8	5·6	6·0	18·6	18·8	19·6	15·4	9·8	2·0	1·8	·4

Similarly, the number of spikelets per ear varied between 14 and 24, and the number of internodes per straw between 4 and 7, with the following frequency distributions:

NUMBER OF SPIKELETS PER EAR

Class	14	15	16	17	18	19	20	21	22	23	24
Frequency	1	0	6	18	35	103	141	141	48	6	1
Percentage in each class	·2	0	1·2	3·6	7·0	20·6	28·2	28·2	9·6	1·2	·2

NUMBER OF INTERNODES PER STRAW

Class	4	5	6	7
Frequency	4	103	366	28
Percentage in each class	·8	20·6	73·2	5·6

In dealing with quantitative variations the application of statistical methods is of great service in obtaining accurate expressions for the amount and range of the variability of each character, and the determination of the mean (M), the standard deviation (σ), and the coefficient of variability (C), or ratio of the standard deviation to the mean of all fluctuating characters of plants, the pedigree of which is known, would be of much value.

Some of these, obtained from investigations of "Swan" wheat, are given below:

		M.	σ.	C, per cent.
Length of ear	mm.	77·72 ± ·184	9·95 ± ·13	12·8
Length of straw	cm.	99·4 ± ·30	14·06 ± ·212	14·1
Length of upper internode	cm.	39·97 ± ·142	6·69 ± ·10	16·7
Length of lowest internode	cm.	2·737 ± ·029	1·21 ± ·02	44·2
No. of internodes per straw		5·836	·513	8·78
No. of spikelets per ear		21·78 ± ·029	1·59 ± ·021	7·3
No. of grains per ear		33·64 ± 3·29	7·55 ± 2·27	22·4
Weight of ears per plant	gr.	16·81 ± ·49	9·03 ± ·34	53·7
No. of ears per plant		5·46 ± ·145	2·7 ± ·103	49·0

The following results obtained by Oetken refer to a Squarehead wheat:

		M.	σ.	C, per cent.
Ear length, 2 good ears . . .	cm.	7·96± ·04	·56±·03	7·1± ·3
Ear length from longest straw .	cm.	7·90± ·04	·65±·03	8·2± ·4
Ear length from shortest straw .	cm.	7·17± ·05	·80±·04	11·1± ·5
Straw length (the longest straw) .	cm.	126·1 ± ·38	5·56±·27	4·4± ·2
Straw length (the shortest straw .	cm.	108·0 ± ·60	8·88±·42	8·2± ·4
Straw length (the average straw) .	cm.	118·2 ± ·37	5·04±·26	4·3± ·2
Difference between longest and shortest	cm.	18·4 ± ·66	8·95±·46	48·6±2·5
Tillering		5·8 ± ·19	2·79±·13	47·8±2·3
Total yield per plant	gr.	33·5 ±1·16	16·53±·80	49·3±2·4
Grain yield per plant	gr.	11·2 ± ·43	5·30±·28	47·4±2·5
Grain yield to total yield . . .	%	32·7 ± ·24	3·31±·17	10·1± ·5
Weight of ear of longest straw .	gr.	2·89± ·04	·58±·03	20·1±1·0
Weight of ear of shortest straw .	gr.	1·95± ·04	·61±·03	31·5±1·5
Average yield of grain per ear .	gr.	1·89± ·03	·38±·02	20·0±1·0
Grains per spikelet		2·37± ·02	·29±·01	12·4± ·7
1000-grain weight for whole plant .	gr.	40·43± ·23	3·56±·19	8·8± ·5
1000-grain weight, 2 good ears .	gr.	41·57± ·35	4·63±·25	11·1± ·6

Although all characters of the wheat plant fluctuate between a higher and lower limit, there are great differences in the extent and range of their variability. Of the characters mentioned above, the number of spikelets per ear, length of straw and ear, number of internodes per straw, and 1000-grain weight vary much less than the yield per plant, weight and yield of grain per ear, and the "tillering" or number of straws produced by each plant.

As already stated, individual variations or fluctuations are not inherited, and are considerably influenced by soil and season; nevertheless, the mean and range of variation of the different characters are hereditary features of the group or population constituting the pedigree cultures raised from a single plant. For example, the grains from an ear 60 mm. long do not produce plants with ears of this length only, but a fluctuating series, having the same mean and standard deviation as those of the pedigree culture from which the original grain was derived.

Correlations.—The different organs of a plant are so co-ordinated with each other that variation in one part involves a simultaneous variation in another. In wheat, for example, variation in the number of straws or tillering is associated with an alteration in the total weight of the plant, and length of growing period with the total yield of grain per plant.

Such *correlated variation* may be positive (+), an increase in one of the characters carrying with it an increase in the other, or it may be negative (−), in which case an increase of one is linked with a decrease in the other.

While in many instances the facts of correlation are undoubted, the

exact nature and causes of the relationships are not understood in all cases, and satisfactory explanations of them cannot always be given.

Where the variations are capable of being quantitatively expressed, the amount of the correlation between a pair of characters can be represented as a coefficient calculated from a correlation table, in which is displayed the frequency distributions of the simultaneous variations of the two characters concerned.

The coefficient of correlation (r) lies between 0 and 1. It is a measure of the extent to which one character varies in unison with another.

When $r=1$ complete correlation is indicated, the variations being controlled by exactly the same causes; this degree of correlation is, however, rarely, if ever, found between any of the characters of living organisms.

When $r => \cdot 9$ correlation is almost complete.
,, $r=\cdot 6$-$\cdot 9$ there is very high correlation.
,, $r=\cdot 3$-$\cdot 6$ there is distinct correlation.
,, $r=0$ there is no correlation.

Correlation between the Number of Spikelets and the Length of the Ear in "Swan" Wheat

Length of the Ear (mm.).

Average Lengths of Classes.

	50. 54	55. 59	60. 64	65. 69	70. 74	75. 79	80. 84	85. 89	90. 94	95. 99	100. 104	105. 109	f_N.
No. of Spikelets. 14	..	..	..	..	..	1	..	..	..	..	..	..	1
15	..	..	..	..	..	..	..	..	..	..	..	..	0
16	..	2	2	..	2	..	..	..	..	..	..	..	6
17	1	4	9	1	3	..	..	..	..	..	..	..	18
18	..	3	10	10	10	..	2	..	..	..	..	..	35
19	..	..	6	17	34	32	11	3	..	..	..	..	103
20	..	..	1	2	37	40	37	17	7	..	..	..	141
21	..	..	..	..	6	19	43	49	19	3	2	..	141
22	..	..	..	..	1	2	5	6	20	5	7	2	48
23	..	..	..	..	..	..	..	2	2	2	..	..	6
24	..	..	..	..	..	..	..	..	1	..	..	..	1
f_L	1	9	28	30	93	94	98	77	49	10	9	2	500

$r=\cdot 749 \pm \cdot 013.$

Below is given a list of some correlations which have been observed in wheat. The extent of the correlation varies more or less with the race and variety of wheat and the external conditions of growth:

Subject Character.	Co-ordinated or Relative Character.	Positive or Negative Correlation.
Length of straw . .	Length of ear	+
,,	Weight of ear	+
,,	Weight of grain in ear	+
,,	No. of grains per ear	+
,,	Grain yield per plant	+
,,	Grain yield per ear	+
,,	Density of ear	−
Number of straws . .	Total weight of plant	+
,,	Length of straw	+
,,	Weight of straw	+
,,	Length of ear	+
,,	Density of ear	−
,,	Weight of grain per plant	+
,,	No. of grains per ear	−
,,	Resistance to frost	+
,,	Late ripening	+
Diameter of straw . .	Length of upper internode	+
,,	Length of lower internode	−
,,	Tillering power	−
Length of the ear . .	Number of spikelets	+
,,	Density of the ear	−
Length of growing period	Total yield of plant	+
,,	Total weight of grain per plant	+
,,	Average size of the grain	+
,,	Starch content of grain	+
,,	Relative nitrogen content	−
Weight of the grain .	Size of the grain	+
,,	Nitrogen content	−
Brittleness of rachis .	Close-fitting glumes	+
Long upper internode .	Heavy ear	+

The following are examples of the size of the correlation coefficient of a number of characters of wheat, based chiefly on data obtained from a few pedigree cultures:

Subject Character.	Relative Character.	r.	
Length of straw . .	Length of ear	·439 ± ·017	Percival
"	"	·292	Roberts
"	No. of grain per ear	·668	"
"	Average yield of grain per ear	·44 ± ·06	Oetken
"	Yield of grains per plant	·08 ± ·07	"
"	"	·294 ± ·032	Love
"	Average weight of grains	·278 ± ·033	"
No. of straws per plant	Weight of plant	·94 ± ·01	Oetken
"	Weight of grains per ear	·834	Love
"	"	·04 ± ·07	Oetken
"	Length of straw	·281	Roberts
"	No. of grains per ear	·180	"
"	Average weight of grain per plant	·013 ± ·032	Myers
Length of ear . .	No. of spikelets	·757 ± ·013	Percival
"	"	·735 ± ·008	"
"	Average length of rachis internodes	·909	Parker
No. of grains per plant	Average weight of grains	·251 ± ·033	Love
"	Yield of grain	·985 ± ·001	"
No. of spikelets per ear	No. of grains per ear	·230 ± ·09	Percival
"	"	·515 ± ·07	"
Weight of straw and ear	Weight of grain per straw	·925 ± ·004	Myers
"	"	·890 ± ·006	"
Weight of ear . .	Weight of grain per ear	·777 ± ·008	Percival
Average weight of grains sown . .	Length of ear	−·511 ± ·015	Waldron
"	Length of straw	−·404 ± ·017	"
Yield of grain . .	Average weight of grains	·327 ± ·031	Love

Sports or Discontinuous Variations

It is a common experience of all who have made a study of pedigree wheats raised from a single grain or ear of a plant that, sooner or later, there appear among the progeny varieties which do not belong to the fluctuations of the particular form, but differ from these in the possession of one or more new characters. They are only occasionally found in the small plots constituting the first or second generations of a selected ear, but turn up with a considerable degree of regularity so soon as from 20 to 100 square yards of the pedigree culture is obtained. Such *sports* or discontinuous variations arise suddenly, and are not connected by inter-

mediates with the parent form. In some cases the new characters are not constant, while in others they are hereditary sports of the latter class, being usually designated *mutations* or *mutants*. There is scarcely a single character normally present in wheat which may not thus arise spontaneously among forms of wheat in which it has not previously been observed, and the new feature may be either a Mendelian dominant or a recessive.

Among beardless wheats bearded forms appear, and among bearded forms beardless plants arise.

In regard to the colour of the glumes, red-chaffed varieties arise among white-chaffed wheats, and white-chaffed plants among red.

Varieties with black awns sport to white- or red-awned forms, and *vice versa*.

Among lax-eared wheats plants suddenly appear with compact ears, and in dense Squarehead wheats varieties with long lax ears are found.

Glabrous glumed forms give rise sometimes to forms with pubescent glumes, and *vice versa*.

Investigations to determine the nature and origin of the sports enumerated have proved that many of them are natural hybrids, and their progeny exhibits simple Mendelian segregation. Breeding tests of others show that they are segregates—heterozygotes, homozygous dominants and recessives—of natural hybrids which have escaped observation in previous seasons. The majority of such examples generally involve only one or two allelomorphic pairs of characters. A few sports, however, which I have observed in pedigree cultures of *T. vulgare*, *T. compactum*, and *T. Spelta* were much more complicated and gave rise to an extraordinarily heterogeneous mixture of descendants. In Fig. 215 is illustrated the remarkable variety of forms obtained from a sport of a Chinese beardless smooth-chaffed bread wheat, received from Chungking under the name " Kwang T'ou Mai." The grains from a single ear were sown in 1911, and from the progeny, which was apparently uniform, a single ear clubbed at the apex and lax at the base, as in ear 1, was selected and its grains sown in 1912. These yielded 57 plants in 1913, one of them a *compactum* form (ear 3) like the upper half of the original clubbed ear, but with pubescent glumes, the rest smooth-chaffed and of uniform density (ear 2).

From the *compactum* sport 36 plants were raised, among which 12 distinct forms were found (line A). Some of these had long lax ears, others possessed intermediate or short and compact ears. Clubbed as well as uniformly dense-eared plants were obtained, the majority beardless, but a few with short awns at the tips of the ears. In regard to the pubescence of the glumes, some were densely hairy, others only slightly pubescent, while several were quite glabrous.

The grains from single ears of each of the 36 " sported " plants were sown separately, the range of the forms of the ears of their progeny being illustrated in line B. In addition to the morphological characters already mentioned, plants with fully-bearded ears appeared in this generation. Examples such as this, if they are cases of Mendelian segregation, involve several pairs of allelomorphic characters.

Some varieties of wheat which have remained constant for a considerable period suddenly give rise to one or more sports.

These cases I regard as hybrids, which are stable under one set of climatic and soil conditions, but have been induced to sport by cultivation in a new environment. Examples which I consider support this view, I observed in two pedigree cultures of Huguenot wheat a peculiar beardless form of *T. durum* (Fig. 146), selected from a crop of Medea (*T. durum*) about 1898 by J. Currell of Arthur River, Western Australia, and supposed to be a hybrid between Medea and Purple Straw (a *vulgare* wheat).

For four years two short rows of 10-12 plants of each culture were raised at Reading annually from single ears of the previous season. These showed no variation until the fifth year, when both cultures sported in the same manner, giving fully-bearded, semi-bearded, and beardless plants of *T. durum*; the numbers of each, however, were too small to admit of any reliable ratios being established.

It may be argued that such an example, like those already mentioned, is merely a case of segregation of a natural hybrid, the crossing of which took place in the season immediately preceding that in which the sporting occurred. This explanation, however, is not satisfactory, for it is very improbable that two separate cultures should have been accidentally crossed in the same season with apparently the same second parent.

From a bearded red-chaffed Squarehead wheat which had been constant for several seasons, Rümker observed the production of a very variable beardless sport under circumstances which excluded mixing of sorts or natural hybridisation as explanations of the appearance of the new form.

The original bearded form was a selection from the progeny of the hybrid Landwheat ♀ × Squarehead ♂.

I have had similar experience with Badger wheat (a selected bearded Squarehead).

Other examples are known among wheats, and Blaringhem states that the hybrid Svanhals barley, constant when grown at Svalöf, reveals its hybrid origin when grown in Flanders and Picardy.

These and similar sports are usually described as mutations, and their new characters are assumed to be due to germinal variation arising independently of segregation and recombination of the hereditary units

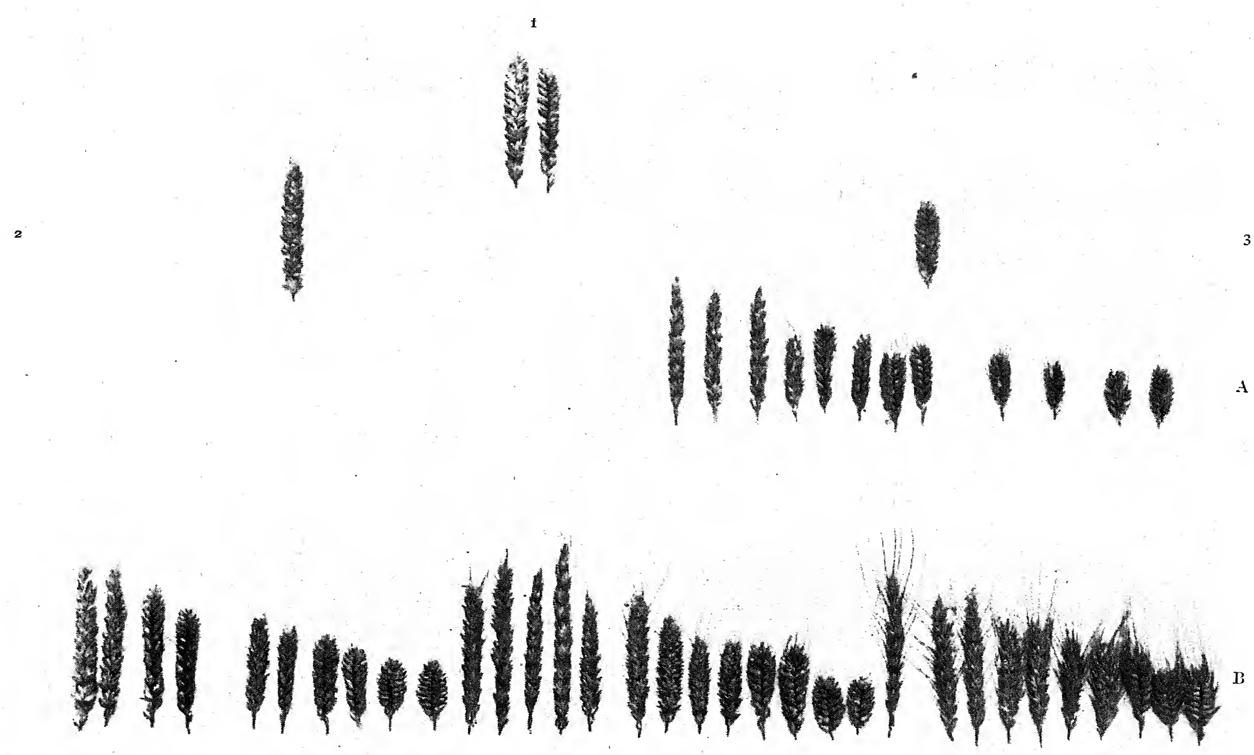


FIG. 215.—(3) "SPORT" FOUND IN PEDIGREE CULTURE OF (1).

A. Forms of the first generation raised from (3).
B. Forms present in the second generation.

of the plants. Without at present being able to offer any explanation of the processes involved, I am inclined to look upon them as the product of hybrids, the ordinary segregation of which has been delayed or inhibited for a time.

The various races of wheat differ considerably in their tendency to sport or mutate; those in which evidence points to their being of hybrid ancestry are much more subject to this kind of variation than the purer races. For example, sports are much more frequent in *T. vulgare* and *T. compactum*, two races which I regard as hybrid (pp. 342, 346), than in *T. durum* or *T. dicoccum*. I have never seen an example in *T. monococcum*, the race which gives no fertile hybrids. Certain forms, such as the Squarehead *vulgare* wheats, are also especially liable to vary in this manner. Changes in the environment appear to stimulate the production of sports. In some seasons, especially those with an abnormally high average summer temperature following severe winters, sports are more frequent than usual in autumn-sown wheat. Rimpau records great variation among Squarehead wheats throughout Germany in 1903, especially among the bearded forms which had before been very constant and pure.

Buffum obtained sports in Black Emmer and a Turkey Red type of *vulgare* wheat immediately after sowing in rich "sagebrush" soil at an altitude of 4000 feet in Wyoming.

Speltoid Mutations.—These sports observed among the descendants of pedigree cultures and hybrids of *T. vulgare* have the narrow open ears and truncate empty glumes of *T. Spelta*; the culms are tall and the ears erect, rigid, and harsh.

Most of them are heterozygotes, which segregate into homozygote normal forms and heterozygote speltoids in the ratio 1 : 1, which Nilsson-Ehle explains by the assumption of the total elimination of male speltoid gametes.

In a few cases segregation occurs into normal forms, heterozygous speltoids and homozygous speltoids in the ratio 1 : 2 : 1, but more often the proportion of speltoid forms is smaller than this owing to the partial failure of male gametes.

I have found considerable numbers of speltoid forms (2, Fig. 173) among mixed samples of *vulgare* wheats from Persia, Central Asia, Spain, and Argentina; these, however, are usually homozygous.

Dwarfs.—Dwarf plants with short culms and compact short ears are found in the F_2 and subsequent generations of hybrids of certain races of wheats. Some of them are fertile, with normal glumes and grain; others are monstrous forms with deformed sterile ears.

I have never observed the production of dwarf mutants among pedigree lines of wheats, nor have I met with clear references to any. Farrer,

however, observed the occurrence in Australia of what he termed " grass-clump plants " among the progeny of many of his hybrid wheats. Richardson also reports their appearance among his crosses in the same country, and Cutler obtained a single specimen, which he describes as a " dwarf wheat," in a plot of Marquis wheat in Saskatchewan. These forms differ from the ordinary crop in producing dense, compact clumps of leaves, from which arise only a few short culms with small ears. Farrer states that they appear among crosses between widely different types of *T. vulgare* only and are first seen in the F_2 generation, though in one instance (a cross between " Bokhara desert " wheat and a Fife-Indian variety) all the F_1 plants (four in number) were " grass-clumps."

There is, I think, little doubt that these are segregates of the ordinary " winter " type, requiring a longer period for completion of their growth than the Australian climatic conditions allow, and are not true " dwarf " plants ; they behave under these conditions exactly as " winter " forms of Bread Wheat do in this country when sown too late in spring or summer to produce ears in the same year (see p. 90), and if protected from drought would doubtless produce normal culms and ears in the following season.

Bud Sports.—This class of variation is exceptionally rare among wheats.

Åkerman describes four examples discovered among the descendants of hybrids of *T. vulgare*. Larger or smaller portions of the ears of these sports have empty glumes which resemble those of *T. Spelta* in form, nervation, and close investment of the grain.

In one of them found in the F_2 of the hybrid Iron × Thule II. wheats, the ear had speltiform empty glumes on one side and normal *vulgare* glumes on the other.

A similar sporting ear was obtained on a plant with five ears, four of which were normal, the plant being one of the F_5 progeny of the hybrid Brown Schlanstedt × Borsum (a Norwegian spring wheat). From the same cross another plant arose having three ears, two normal and one with the upper part speltoid, and the lower portion speltoid on one side and normal on the other.

In the fourth example all the spikelets of the upper part of the ear possessed speltiform empty glumes, but in the four lowest spikelets one of the empty glumes of each spikelet was speltiform and the other normal *vulgare*.

The speltoid empty glumes in all these cases are erect and nearly parallel to the rachis, the corresponding opposite glumes being arranged almost at right angles to them. The affected spikelets are turned to one side in a manner similar to some of those in Fig. 179.

Åkerman regards these as periclinal or sectorial chimaeras. Three of the sports, it was suggested, were normal plants surrounded by a hetero-

zygote speltoid epidermis, since they gave only normal progeny. From the fourth example some of the grains produced speltoid heterozygote plants which segregated in the ratio of 1 : 1. In this type one or more subepidermal cell-layers from which the gametic cells arise were evidently heterozygote.

I have never observed white-chaffed and red-chaffed ears or white-grained ears and red-grained ears upon the same plant, but plants are not infrequently seen bearing fully-bearded and almost beardless ears upon the same individual, the fully-bearded ears being always found on the first-formed culms.

Plants possessing both "clubbed" and lax ears of uniform density are not infrequently met with at Reading, the lax ears being borne on the youngest straws. Rimpau observed both long lax ears and short denser Squareheads upon an F_1 plant of the hybrid

Frankenstein (lax-eared *vulgare*) × Igel (*compactum*), and Caron-Eldingen also describes and figures a plant possessing both lax and "clubbed" ears of two different types which he explains as resulting from a twin grain (p. 359).

Possibly some of these variations may be manifestations of natural reduction of vigour or inadequate nutrition of the later-formed "tillers" of the plants and hardly to be classed as examples of bud sports.

Ohlmer, Preul, and others attribute the clubbing of the ears of Squarehead wheats to an excess of nitrogen and diminished water-supply in the early stages of development of the culm and ear, and my own observations support this view.

Teratological Sports.—Besides the sports which are concerned with the discontinuous variation of the normal characters of the wheat plant, there are *teratological sports*, "monstrosities" or "freaks" possessing abnormal features, such as twin ears, supernumerary spikelets, and other examples mentioned below.

They are comparatively rare and their cause unknown.

i. Bent and Sinuous Upper Internodes.—In some individual culms the upper internodes are bent completely round so that the ear is parallel with the straw and its apex downwards. In others the upper internode is sinuous just beneath the ear. Both these malformations are more frequent in *T. turgidum* and *T. durum* than in other races, and are often seen in the deformed progeny of hybrids between distinct races (Fig. 220).

ii. Malformed Upper Internode and Leaf.—A common deformity is the arrested development of the upper internode of the culm, the first node being less than an inch from the base of the ear. In such cases the ear is usually normal, but the uppermost leaf is more or less malformed,

its sheath and reduced blade sometimes appearing like a spathe of the inflorescence.

This deformity is met with in all races of wheat and is caused by a parasitic fungus.

iii. Variegated Leaves.—Plants with white longitudinal stripes along the leaves are occasionally found in *T. dicoccoides* and *T. vulgare*. In the examples I have seen, the abnormality is hereditary and chiefly confined to the young leaves, those of the culm being uniformly green. The edges of the variegated leaves are usually pink.

iv. Branched Ears.—Many forms of *T. turgidum* have branched ears, abnormal secondary axes of variable length arising from notches of the rachis in the place of ordinary spikelets. The character is also seen in *T. dicoccum*, from which I consider that *T. turgidum* has arisen. It not infrequently appears among hybrids of *T. dicoccum*, and is seen occasionally in *T. polonicum*, but is uncommon in other races. The development of secondary ears is hereditary in certain forms, but the degree of branching is very largely dependent upon climatic and soil conditions. The morphology of these ears is discussed in the description of Miracle or Mummy wheat (p. 256).

v. Twin Ears.—Two ears are occasionally found at the apex of a single straw. Shirreff records such a variation, both the twin ears being perfect in form, one containing forty-five grains, the other thirty-six. In all the cases I have seen, it is the rachis which bifurcates, as in Fig. 216, and not the culm. An example with the rachis divided near the base is figured in the *Gardeners' Chronicle and Agricultural Gazette* for 1849 (p. 363).

The production of twin ears I have only seen in *T. vulgare*. It is not hereditary and is much less common, and quite a different phenomenon from the branching of the ears so frequently seen in forms of *T. turgidum*.

vi. Short Ears.—Short stumpy ears consisting of three to seven spikelets are found occasionally in *T. vulgare* and *T. turgidum*.

The spikelets are of normal size and form and develop well-filled grain. The terminal spikelet, unlike the arrangement in normal ears, is parallel to the rest. Possibly the true apex of the rachis is destroyed in its early development by a parasite, although there is no evidence of such damage in the mature ears.

The variation is not hereditary.

vii. Small Malformed Ears, generally on short sinuous culms, appear not infrequently among the progeny of hybrids between distinct races of wheat, more especially when *T. dicoccoides* or *T. dicoccum* is one of the parents (see Fig. 220). A number figured by Buffum were obtained among the F_1 of a cross between a " mutating " *T. dicoccum* and a " sport " of Turkey Red wheat (*T. vulgare*).

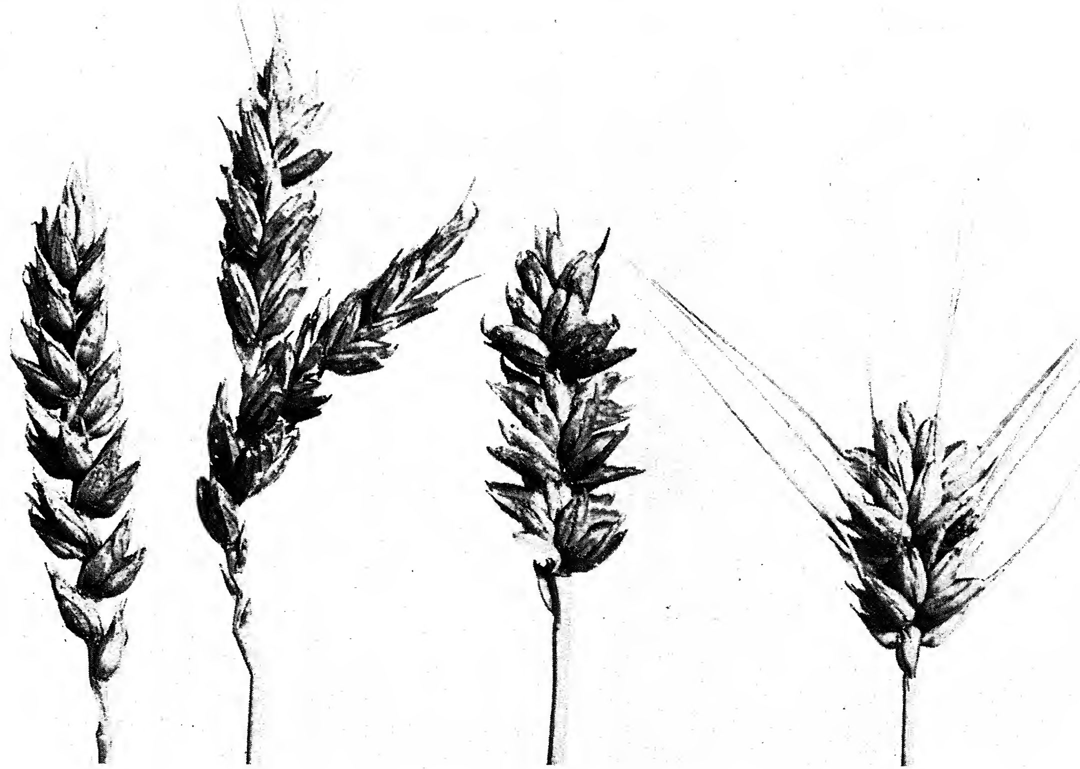


FIG. 216.—TERATOLOGICAL FORMS OF WHEAT EARS.

1. Ear with duplicate spikelets. 2. Twin-ear. 3 and 4. Short ears.

viii. Supernumerary Spikelets.—These sometimes arise singly by the side of a normal spikelet and arranged at right angles to it. Both spring from the same notch of the rachis.

Additional spikelets are also frequently found growing from the rachis immediately below the points of insertion of the normal spikelets and generally arranged parallel to them (1, Fig. 216). In some cases they produce one or two grains, but are often rudimentary, consisting only of minute misshapen glumes.

These variations, which I have found most often in Chinese *vulgare* wheats, occur chiefly in ears of the latest tillers, the ears which develop first being usually quite normal; the variation does not appear every season, though a form which has once shown it may produce it again.

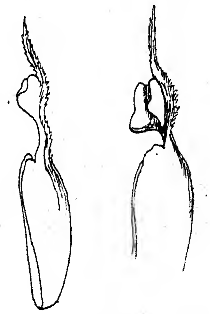


Fig. 217.—Flowering glumes of a Semiretchensk form (*T. vulgare*) (see 2, Fig. 179).

ix. Awns.—I have not observed many variations in the structure or general morphology of the awns of wheat.

In a Persian form of *T. vulgare* the short awns of the flowering glumes of some of the spikelets sometimes have a thin membranous outgrowth on each side, about half-way between the tip and base of the awn (Figs 179, 217). The peculiarity is not constant.

In several Central Asiatic forms of beardless *T. vulgare* the short awns at the apex of the ears are often strongly curved and sometimes bent into the form of a hook.

x. Twin Grains.—Malformations of the parts of the flower are rare in wheat. The only case recorded appears to be that figured by Caron-Eldingen, of a twin grain with two embryos, developed from two united ovaries.

CHAPTER XXV

HYBRIDISATION AND WHEAT HYBRIDS

WHILE self-fertilisation may be considered the rule, examples of natural hybrids among wheats are much more frequent than is generally assumed.

Howard states that cross-fertilisation is common among wheats in the hot dry climate of Northern India.

Körnicke observed numerous hybrids among his cultures in Germany, and Godron, Vilmorin, and others note the occurrence of cross-fertilisation in France.

Nilsson-Ehle and Kajanus state that in Sweden a small amount of crossing takes place at Svalöf and elsewhere, and renders it difficult to preserve the purity of select varieties when these are multiplied and grown on a large scale.

Shirreff records the crossing of some of his wheats, and natural hybrids are found in small numbers annually at Reading both in experimental pedigree cultures and in the open fields.

Many of the " sports " discovered among wheats in all parts of the world have proved to be natural hybrids or their segregates.

A few wheats are distinctly protogynous, but in the majority the reproductive organs ripen at the same time.

There are considerable differences among them in regard to their tendency to hybridise. While many forms are probably always self-fertilised, others cross more or less readily when grown in proximity to another kind, and in such instances it is found that crossing sometimes takes place in one way only, the reciprocal hybrid being never obtained. This is most obviously the case with the wild *T. dicoccoides*, but Nilsson-Ehle records the natural hybridisation of Swedish Velvet Chaff (♀) and Pudel wheats (♀) when grown in mixtures with another form of *T. vulgare* (Old Brown " Landwheat " ♂), the reverse crosses being never found.

Since natural hybridisation occurs among widely different races and varieties when grown on small plots, it may be assumed that it takes place also in the field between plants of the same crop, and it is possible

that the greater vigour and yield of some wheats may be due to the fact that they cross more frequently than the less prolific types.

The production of artificial hybrids of wheats appears to have been first attempted in this country by Thomas Andrew Knight about the end of the eighteenth century. After successfully crossing peas he tried the hybridisation of wheat, but states in his *Essay on the Fecundation of Vegetables* (1804) that it "did not succeed to my expectations," and goes on to say: "I readily obtained as many varieties as I wished by merely sowing the different kinds together: for the structure of the blossom of this plant (unlike that of the pea) freely admits the ingress of adventitious farina, and is thence very liable to sport in varieties."

In 1846 Mr. Maund of Bromsgrove exhibited hybrid wheats at a meeting of the English Agricultural Society (*Gardener's Chronicle*, 1846, p. 601), and in the same year Hugh Raynbird produced the hybrid Piper's Thickset ♀ × Hopetoun ♂, the female parent a red-chaffed wheat with short dense ears, the pollen parent a lax-eared form with white chaff. The few hybrid grains obtained were sown in September and the "roots" divided in January. "The produce," he states, "was many kinds both of red and white wheat; some of the ears bore a perfect resemblance to the Piper's Thickset, others partook of the character of the Hopetoun in everything except in the colour of the chaff, others had half the ear thin and open, and the rest close set, thus in the same ear showing the characteristics of each kind."

One of Raynbird's hybrids was awarded a gold medal in 1848 by the Highland and Agricultural Society of Scotland, and several produced by Maund and Raynbird were exhibited at the Great Exhibition of London in 1851.

These were the first hybrid wheats grown on a large scale.

From about 1850 to 1870, Patrick Shirreff of Haddington in Scotland paid especial attention to the improvement of cereals and produced several hybrid wheats.

In the early 'seventies of the nineteenth century Pringle and Blount in the United States, Vilmorin in France, and Rimpau and Heine in Germany were all actively engaged in hybridising wheats. Since that date the crossing of this cereal has been extensively practised in a great many countries.

Little is known of the conditions upon which success or failure depends in the artificial hybridisation of wheats. Some crosses are difficult, while others are exceptionally easy. As a rule, wheats of different races do not cross so readily as varieties and forms of the same race, but it is occasionally observed that pollinations carried out at the same time upon different ears of the same plant are not all equally productive of grain.

Very slight differences in the state of development of the styles and

age of the pollen, the temperature and moisture of the atmosphere at the time of pollination, and the time of day at which the operation is performed, all have an influence upon the result.

While pollinations may be effective at all times of the day, I have had the best returns from those made in the morning before 10 A.M. At that time the tendency to rapid drying of the temporarily exposed parts of the flower is much less than during the hotter part of the day.

The hybrid grains are frequently smaller and more shrivelled than self-fertilised grains of the same ear, more especially when the two parents belong to different races, and small imperfectly formed grain sometimes results after cross-fertilisation between two nearly related forms, although plump grains are equally frequent.

The embryos of shrivelled hybrid grains are usually delicate, and special care is required in rearing them. It is best to sow the grain in pots under glass rather than in the open soil, where the risk of destruction of the young plants by frosts, rain, and pests is greater.

The shrivelled endosperm of hybrid grains is probably connected with the fact that, like the embryo, it is of hybrid origin, or possibly its feeble development is attributable to the failure of the second male gamete to unite with the fusion-nucleus of the embryo sac.

The method of the artificial hybridisation of wheat is simple, nevertheless there are certain important points of detail to which it is useful to direct attention.

Since anthesis commences usually in two to five days after the escape of the ear from the upper leaf-sheath, crossing must be undertaken during that period or the chances of finding flowers in which the anthers have not already shed their pollen on the adjacent stigmas will be small.

After selecting the grain-bearing female parent, the following is the plan of operations which I adopt :

1. Cut off the upper third of the ear with fine pointed scissors and pull off completely four or five of the lowest spikelets.

2. Of the remaining spikelets remove completely every alternate one on both sides of the rachis.

3. Take hold of the tips of the few spikelets left and pull outwards and downwards; this removes the upper florets of the spikelets, and leaves for crossing only the two lowest and largest florets of each.

4. Gently press the glumes of the florets to be emasculated, and insert the point of a pair of closed forceps between the upper edges of the glume and palea. On releasing the forceps the glumes are separated and the anthers are exposed to view.

5. If the anthers are green and erect they can often all be removed together, but if further advanced in their development they should be removed singly, care being taken not to burst them in the process.

In some wheats, two of the anthers are hidden behind the overlapping edges of the palea and require great care in their removal. Somewhat blunt-pointed forceps are less liable to break the anthers than those with very fine points.

6. Select an ear of the pollen parent, and with scissors cut off the upper half of the glumes of a few of its median spikelets. With forceps remove any thus exposed anthers which are bright yellow, and after pinching them dust the escaping pollen on the styles of the emasculated flower; leave the broken anther in contact with the styles and allow the glumes to close.

7. Enclose the crossed ear in an envelope of thin waterproof paper, and with cotton tie the lower open end of the envelope round the upper part of the straw so as to prevent the access of foreign pollen or insects.

Where waterproof envelopes are not available, take a strip of thin soft paper six inches wide and wind it three or four times round the crossed ear and upper part of the straw; tie above and below the ear to prevent foreign pollination.

8. Label the crossed ear indicating the respective parents and date of the cross.

9. After a week examine the crossed ear, and if the stigmas are withered remove the covering altogether.

(If the stigmas are receptive, fresh pollen applied to them germinates immediately and fertilisation is effected in forty-eight hours or less.)

Raynbird, Shirreff, Pringle, and Vilmorin, among the earlier hybridists, observed the extraordinary multiplicity of forms among the descendants of hybrid wheats, but it is only since the re-discovery of Mendel's laws of inheritance that any explanation has been given of the cause of the diversity.

In recent years there has been an accumulation of more or less precise knowledge of the mode of inheritance of the chief characters of the species and races of wheat, which is summarised in the following pages. In making clear some of the points which were previously obscure, the Mendelian concepts of heritable factors and gametic purity have been invaluable, but much remains to be discovered before all the facts of inheritance in the highly complex hybridised wheat plant can be satisfactorily explained.

Inheritance of the Chief Characters of the Wheat Plant

Erect and Spreading Habit (p. 69, Figs. 65, 66).—Hybrids of wheats with these characters are intermediate, the F_2 segregating in the 1 : 2 : 1 ratio.

Early and Late Ripening Period.—These characters are correlated with the foregoing allelomorphic pair, early wheats always having upright young shoots, while in the latest forms the young shoots are prostrate.

Hybrids are intermediate with semi-erect young shoots (B, Fig. 66), and segregate in F_2 in the 1 : 2 : 1 ratio.

Hollow and Solid Straw.—In the majority of wheats of the *vulgare* and *compactum* races, the culms are comparatively wide and hollow with thin walls; those of *T. durum*, *T. polonicum*, and *T. turgidum* are smaller in diameter and full of pith, or thick-walled with a very small central cavity.

The hollow form is dominant over the solid straw, and F_2 segregation is in the 3 : 1 ratio.

Pubescent and Glabrous Young Leaves.—The surfaces of the young leaves of *T. durum* are nearly or quite glabrous, those of other races being more or less densely clothed with hairs.

In general the pubescent leaves of *T. dicoccum* and *T. turgidum* are dominant over the less hairy and glabrous leaves, but the segregation of the characters in the F_2 generation has not been adequately investigated.

Normal and Branched Ears.—According to Tschermak, the normal condition is dominant over the branched ear of "Mummy" wheat (*T. turgidum*, var. *mirabile*) (Fig. 160).

Fragility and Toughness of the Rachis.—In the two wild wheats *T. aegilopoides* and *T. dicoccoides* the rachis of the ripe ear separates transversely at the nodes, each spikelet with an internode of the rachis attached falling to the ground when the ear is slightly shaken.

In three cultivated wheats, *T. monococcum*, *T. dicoccum*, and *T. Spelta*, the rachis is also fragile, but in a lesser degree.

In contradistinction to these are the rest of the cultivated wheats in which the rachis is tough and does not become disarticulated even under the rough treatment of thrashing.

i. *Brittle-eared* × *Brittle-eared.*

ii. *Brittle-eared* × *Tough-eared.*—The crossing of two brittle-eared wheats gives a constant brittle-eared progeny, and fragility of rachis behaves as a dominant character when a brittle-eared wheat is crossed with a tough-eared form.

iii. *Tough-eared* × *Tough-eared.*—Hybrids of varieties belonging to the same tough-eared race usually have constant tough-eared descendants, but where the two plants crossed belong to different tough-eared races, brittle-eared forms sometimes appear in the F_2 and subsequent generations.

H. Vilmorin observed brittle-eared forms resembling *T. Spelta* among the F_2 generation of the hybrids, *T. vulgare* (Blé Seigle) × *T. turgidum* (Poulard Blé Buisson), and *T. vulgare* ♀ (Chidham d'automne) × *T. durum* ♂ (Ismaël).

Love and Craig record the appearance of two plants with fragile ears similar to those of wild *T. dicoccoides* out of 113 plants of the F_2 generation of the cross *T. vulgare* ♀ (Early Red Chief) × *T. durum* ♂ (Marouani).

The numbers suggest the 63 : 1 ratio of a Mendelian three-factor hybrid.

Lax and Dense Ears.—Extensive investigations have been made regarding the inheritance of the lax open ears and the denser-eared " Squarehead " forms of *T. vulgare* as well as the short dense ears of *T. compactum*.

The researches of Nilsson-Ehle have shown that the lax character of *T. vulgare* is often dependent upon two (or possibly more) independent factors (L_1 and L_2) over which the single factor (C) for short ear or *T. compactum* is dominant.

i. *Lax* × *Lax*.—Hybrids of two lax-eared forms in which both factors for laxity are present give rise to lax-eared descendants only. Where the lax-eared wheats have the constitution L_1l_2 and l_1L_2 respectively, in the F_2 there arise plants (L_1 L_2) with more open ears than either of the grandparents and Squareheads (l_1 l_2) in which both factors are absent.

ii. *Lax vulgare* × *T. compactum*.—In most cases the *compactum* character is dominant and the F_2 segregates approximately in the ratio 3 dense-eared : 1 lax-eared.

In some instances, however, the dominance is incomplete, and grouping into two classes is not possible owing to the existence of an almost continuous series of intermediates of varying ear-density between the lax and compact ears of the grandparents.

For further discussion of these characters see pp. 401-405.

Colour of the Awns.—The heredity of awn colour has not been closely examined. It probably agrees with that of glume colour, black and red being dominant to white and black dominant to red.

The development of the dark pigment in the awn like that of the glumes is greatly influenced by climatic conditions, a fact which makes the determination of its inheritance specially complicated.

Presence and Absence of Awns.—The possession of awns or beards is a primitive character and is common to all races of wheats. In addition to fully-bearded plants, so-called " beardless " wheats are abundant in the four races *T. vulgare*, *T. compactum*, *T. sphaerococcum*, and *T. Spelta* ; in these the awns are absent or reduced to 1 cm. or less in length.

The following are the chief results of investigations concerning the inheritance of the fully-bearded and beardless characters :

i. *Bearded* × *Bearded*.—The crossing of two bearded forms gives a bearded F_1 generation, and the character is continued in all subsequent generations so long as the wheats belong to the same race. Where the plants belong to different races the F_1 generation is also usually bearded, but in some cases beardless as well as bearded forms appear in the F_2 and later generations : an example of the latter is recorded by Vilmorin,

who obtained a beardless *vulgare* form among the descendants of the hybrid *T. polonicum* × *T. turgidum*, var. *lusitanicum* (Pétianelle blanche), both of which are bearded.

ii. *Bearded* × *Beardless*.—In the cross between the bearded *T. dicoccum* and the beardless *T. sphaerococcum* (p. 392) the bearded character was completely dominant in F_1, and plants as beardless as the *T. sphaerococcum* parent were not found in the F_2 or F_3 generations. In other crosses, especially where the wheats belong to the same race, the beardless character is dominant, the bearded recessive.

As explained elsewhere (p. 104), the term "beardless" includes the rare wheats in which awns are entirely absent from the ears, and the very common group with awns from ·3 cm. to about 1 cm. in length on the spikelets of the upper fourth of the ear.

In the majority of records of crosses between bearded and beardless wheats the latter belonged to the short-tipped group. The F_1 generation of such hybridisation has frequently been described as beardless, the beardless character being dominant, and subsequent segregation in F_2 was stated to occur in the ratio of 3 beardless dominant : 1 bearded recessive.

This view of the inheritance of awns requires modification, since the complete dominance of beardlessness is rarely seen. C. E. Saunders (*Report of the Third International Conference on Genetics*, 1907, p. 370) referred to the production of semi-bearded plants in the F_1 generation of crosses of bearded and beardless forms; out of some 300 of these hybrids he found that:

15 per cent were more than one-quarter bearded.
59 per cent were one-quarter bearded.
20 per cent were nearly beardless.
6 per cent were beardless.

Fully-bearded F_1 plants were not observed, and he says "the number of plants which could fairly be called beardless was very small."

In F_2 he obtained fully-bearded and beardless plants with an unclassifiable series of intermediates.

No doubt the particular length of awns of the heterozygote F_1 generation depends on the difference of the parent forms employed in the cross, but the fact that beardlessness is but imperfectly dominant is now quite clear. The early inaccurate conclusion of complete dominance of beardlessness and the 3 : 1 segregation in the F_2 generation was due to the confusion of what may be termed "semi-bearded" heterozygotes with the so-called "beardless" homozygous plants possessing short awns at the tips of the ears.

When the latter "beardless" forms of *T. vulgare* are crossed with

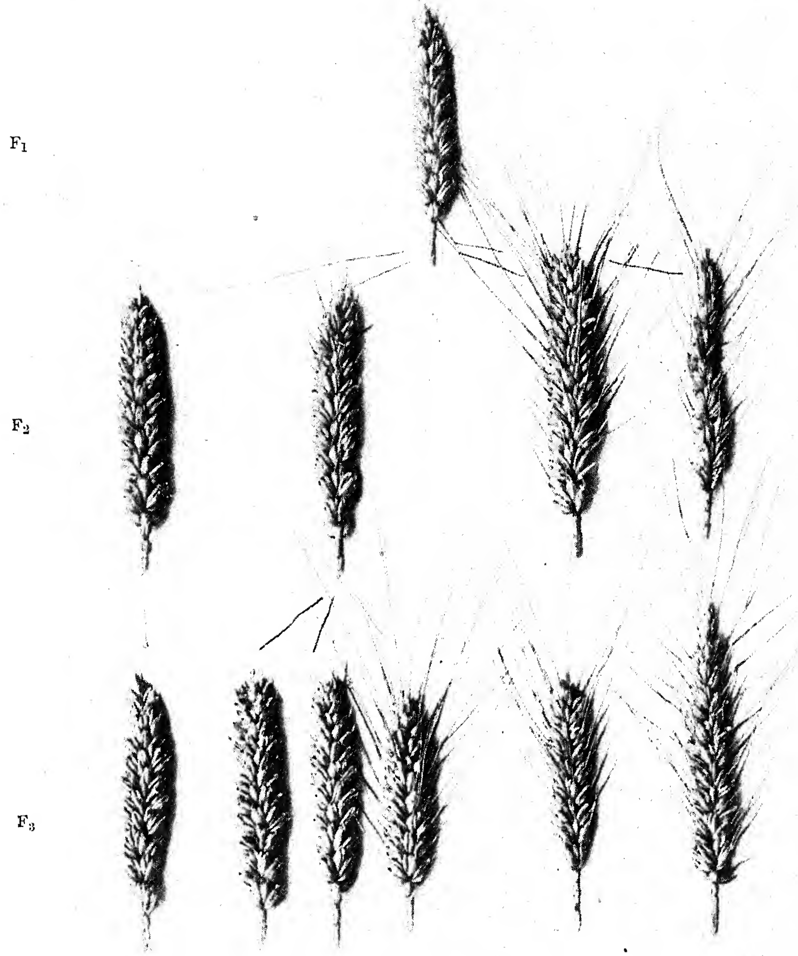


FIG. 218.—HYBRID (F_1) OF BEARDED × BEARDLESS WHEAT, with F_2 and F_3 segregates.

typically bearded forms of the same race having awns 6-9 cm. long, the F_1 plants have ears which on careful examination are readily distinguished from those of the beardless parent, the awns of the spikelets of the upper quarter of the ear being generally from 1·5 to 3 cm. long; the influence of the bearded parent is also visible in the points on the flowering glumes of the lower portion of the ear, for these, though short, are distinctly longer than those of the corresponding glumes of the beardless parent used in the cross.

It is true that in the majority of cases the "semi-bearded" heterozygotes are not exactly intermediate, but have awns much nearer in length to those of the "beardless" than to the fully-bearded homozygous parent; they are nevertheless distinct from "beardless" plants and can be readily separated from them in nearly all cases by eye inspection alone.

The F_2 generation from these "semi-bearded" F_1 hybrids consist of "beardless," semi-bearded, and bearded plants in the ratio 1 : 2 : 1. This has been established by numerous workers, and I have repeatedly investigated natural hybrids between bearded and "beardless" forms of *T. vulgare* with the same result.

A. and G. L. C. Howard have made observations on several crosses between bearded and quite beardless wheats belonging to *T. vulgare.*

The F_1 generation of these crosses had ears with very short tips to the apical spikelets.

In the F_2 generation were plants with completely beardless ears and a series of forms with awns of various lengths, the ratio of the more or less bearded to the quite beardless examples being 15 : 1.

The character and distribution of the bearding among 986 plants of an F_2 generation is indicated below:

	Fully bearded.	Almost fully bearded.	Half bearded.	Tips of varying Length.	Quite beardless.
	61	65	124	673	63
Ratio .	1 :	1 :	2 :	10·7 :	1
	$\underbrace{\qquad\qquad}_{14\cdot 7}$			:	1

The dihybrid ratio observed suggests that two factors are concerned in the production of the fully-bearded ear, one factor being responsible for short or "tip" beards, the other when combined with this giving rise to long awns.

The fully-bearded plants, according to the Howards' view, contain two factors, B and T, the former representing the "long," the latter the "short" factor.

The gametic constitution of fully-bearded plants would be represented by BBTT, the short-tipped plant by bbTT, and the strictly beardless by bbtt.

Crossing a fully-bearded (BBTT) with a beardless plant (bbtt) would give an F_1 of the constitution BbTt, which in F_2 would produce:

1 BBTT (fully bearded) + 4 BbTt (very short tips) + 2 BbTT (nearly bearded) + 2 BBTt (half bearded) + 1 bbTT (short tips) + 2 bbTt (minute tips) + 1 BBtt (long tips) + 2 Bbtt (very short tips) + 1 bbtt (quite beardless).

The fully-bearded, quite-beardless, "long-tipped," and "short-tipped" plants of the F_2 generation just mentioned bred true in F_3; later the two latter were proved to contain the respective constituent factors which on combination gave rise to the fully-bearded character.

These results, although probably of limited application, are of much interest and help to explain the existence of semi-bearded "long-tipped" forms (BBtt), which breed true, as well as the production of fully-bearded wheats from the crossing of forms which would ordinarily be classed as "beardless" (see below).

A repetition and extension of the work of crossing bearded and the various "beardless" forms with accurate measurement of the awn lengths of the descendants and mathematical analysis of the results is much to be desired.

Tschermak states that in the two hybrids Fürst Hatzfeldt (beardless) × Galician (bearded) and Mold's white (beardless) × Hungarian (bearded) the bearded character was lost and did not appear among the descendants.

iii. *Beardless* × *Beardless*.—In almost all cases the crossing of two "beardless" forms results in "beardless" offspring both in the F_1 and all subsequent generations.

Rimpau, however, observed a small number of constant bearded plants among the progeny of the second generation of a cross between two beardless wheats, Saxon "Land" wheat and Squarehead, and Spillman obtained bearded forms from the cross Little Club × Farquhar, both beardless parents.

The Howards also record the production of fully-bearded plants in F_2 from the crossing of "long-tipped" and "short-tipped" "beardless" wheats. Assuming the gametic constitution of the parents to be BBtt and bbTT respectively, the F_1 would be represented by BbTt, and, as explained above, some of the descendants of this hybrid would be fully bearded in the F_2 generation.

It is, however, improbable that this explanation covers all cases of the appearance of fully-bearded plants among the progeny of crosses of "beardless" wheats.

Colour of the Glumes.—The glumes of wheat are generally described as some shade of black, red, or white, the red embracing various shades of brown or red, and the white various shades of yellowish-white. Black and red are more or less dominant over white, and black also dominates the red tints.

i. *Black* × *Red*.—According to Tschermak, white-chaffed individuals sometimes appear among the descendants of this cross, and Rimpau obtained white-glumed forms in the F_2 generation of a cross between a bluish-black chaffed *T. turgidum* and a red-chaffed *T. vulgare* (p. 400).

ii. *Black* × *White*.—Tschermak states that the F_2 of this cross is of complicated character, but the ratio of the pigmented to the white forms is 3 : 1.

From a cross of Black Emmer (*T. dicoccum*, var. *atratum*) × a white-chaffed *T. sphaerococcum* I obtained in F_2 forms with the following chaff colours: uniform black, red, and white, and chaff of these tints with black outer margins. A similar series was obtained by Kezer and Boyack in the F_2 of the hybrid Black Emmer × a white-chaffed *T. vulgare* (p. 393).

iii. *Red* × *Red*.—The descendants of this cross are generally some shade of red, though, as indicated later, white individuals may arise in F_2 from the hybridisation of two red forms.

iv. *Red* × *White*.—Very numerous hybrids have been raised between red-chaffed wheats and white-chaffed wheats: in the majority of these cases the F_1 is intermediate in colour, and the segregation in the F_2 generation of the ordinary monohybrid type 3 red : 1 white, or 1 red : 2 pale red : 1 white, the colour being dependent upon a single pair of Mendelian factors. In such wheats each of the many shades of red appears to have its own special factor.

In crosses made between white wheats and some red-chaffed Swedish "Landwheats" Nilsson-Ehle found that the segregation in F_2 was that of a dihybrid cross, viz. 15 red : 1 white.

He showed that the red colour in these cases is not due to a simple factor but to two different and separately inherited red factors; each of these by itself produces a red tint, not necessarily of the same intensity, and when acting together they have an additive or cumulative effect, the colour increasing with the number of doses of the colour factors present in the zygote.

If the two red factors are represented by R_1 and R_2 and their absences by r_1 and r_2 respectively, a red-chaffed wheat (R_1R_2) when crossed with a white-chaffed variety (r_1r_2) results in a heterozygote F_1 of the constitution $R_1R_2\ r_1r_2$.

The sixteen possible zygotes of the F_2 generation with their respective doses of red factors are shown in the following diagram:

Gametes.	R_1R_2.	R_1r_2.	r_1R_2.	r_1r_2.
R_1R_2	R_1R_2 R_1R_2 (4)	R_1r_2 R_1R_2 (3)	r_1R_2 R_1R_2 (3)	r_1r_2 R_1R_2 (2)
R_1r_2	R_1R_2 R_1r_2 (3)	R_1r_2 R_1r_2 (2)	r_1R_2 R_1r_2 (2)	r_1R_2 R_1r_2 (2)
r_1R_2	R_1R_2 r_1R_2 (3)	R_1r_2 r_1R_2 (2)	r_1R_2 r_1R_2 (2)	r_1r_2 r_1R_2 (1)
r_1r_2	R_1R_2 r_1r_2 (2)	R_1r_2 r_1r_2 (1)	r_1R_2 r_1r_2 (1)	r_1r_2 r_1r_2 (0)

From only one (r_1r_2 r_1r_2) out of the sixteen zygotes are all the red factors absent: this will be white, the rest, having from one to four colour-factors, will be of several shades of red.

When a wheat with deep red chaff, due either to one or two factors, is crossed with a white-chaffed variety, the glume colour of the heterozygotes in F_2 is always an easily recognised red, and homozygous reds even of the lighter shades are found to be distinct from white.

Where the coloured parent of the cross is of a light reddish tint the heterozygotes are very pale and sometimes difficult to distinguish from the homozygous whites.

Some of the F_2 individuals classed as white were found by Nilsson-Ehle to be in reality heterozygotes which split in F_3 into red, pale red, and white-chaffed plants. Owing to the confusion between these heterozygote white and the pure white, the experimental results of segregation may appear not to conform to the ordinary 3 : 1 or 15 : 1 ratios.

In Nilsson-Ehle's crosses of red and white spring wheats the total numbers obtained in F_2 were 2625 red : 987 white = 2·7 red : 1 white, and in some of the individual crosses the apparent splitting was 2·3 or 1·5 red to 1 white, the number of plants classed as white-chaffed being too high.

In consequence of the cumulative effect of two red factors the cross $R_1r_2 \times R_2r_1$ would, of course, lead to the production of forms containing both R_1 and R_2, and therefore darker in colour than either parent, together with some white individuals (r_1r_2 r_1r_2) lacking the colour factors altogether.

v. *White* × *White*.—The F_1 of this cross has invariably white chaff, but the occurrence of red-chaffed plants is recorded by Shirreff in the F_4 generation of the hybrid Shirreff's Bearded white ♀ × Talavera ♂, both white-chaffed wheats.

PUBESCENT AND GLABROUS GLUMES.—Pubescence and smoothness of glumes usually constitute an allelomorphic pair of characters, pubescence being dominant, and segregation of the F_2 is in the ratio 3 pubescent : 1 smooth-glumed form.

In some instances, however, the hybrid (F_1) between a velvet-chaffed and smooth-chaffed wheat is more or less intermediate, the degree of pubescence varying considerably; in these hybrids segregation in F_2 follows the 1 : 2 : 1 ratio.

In the hybrid between a pubescent and beardless *T. vulgare* (Velvet Kolben) and a pubescent and bearded form of *T. compactum* (Igel) Rümker obtained both glabrous and velvet-chaffed plants in the F_2 generation in the ratio 1 glabrous : 3 velvet (p. 403), and a similar ratio of forms with glabrous and pubescent glumes appeared in the F_2 of my hybrid between two pubescent-chaffed wheats, *T. dicoccum* ♀ × *T. sphaerococcum* ♂ (p. 392).

Pubescence was found to be linked with black chaff in hybrids of Black Emmer with *T. vulgare* (p. 394) and *T. sphaerococcum* (p. 393).

CLOSE-FITTING AND LOOSE GLUMES.—In *T. dicoccum* and *T. Spelta* the glumes firmly invest the grains, while in *T. vulgare*, *T. turgidum*, *T. durum*, and some other wheats the glumes loosely enclose the grain.

The close-fitting glumes of *T. Spelta* are dominant over the loose glumes of other wheats except in hybrids with *T. turgidum*, in which, according to Kajanus, the close-fitting character is recessive.

LONG AND SHORT GLUMES.—For inheritance of the long glume of *T. polonicum* see pp. 394-399.

KEELED AND ROUNDED GLUMES.—The keeled character of the glumes of *T. durum*, *T. turgidum*, and *T. Spelta* is dominant over the rounded glume character of *T. vulgare* and *T. compactum*.

BROAD AND NARROW GLUMES.—The broad truncated glumes of *T. Spelta* are dominant over the narrower-pointed glumes of other wheats.

FORM AND SIZE OF GRAIN.—Several of the different races of wheat possess grains of characteristic shape and size which can be recognised without much trouble, although they are difficult to describe.

The grains of hybrids between the several races usually show the characters of both parents, but little accurate research into the features of hybrid grains has been made except in regard to the grain-length of crosses of *T. polonicum* with *T. durum* which was investigated by Engledow. The mean length of the grain of the *T. polonicum* used was about 10·2 mm., that of the *durum* parent 7·7 mm.

The F_1 grain was intermediate. In respect of size of grain three types were found in F_2 with the following mean grain-lengths: 8·84, 8·67, and

8·33 mm., representing the extracted *polonicums*, heterozygote intermediates, and extracted *durums* respectively.

The frequencies of the three types agreed with those found for the glume-lengths of the F_2 of the same cross (p. 396), which suggests a 1 : 2 : 1 ratio.

No grains were found as long as those of the grand-parental *polonicum* and none as short as those of the *durum* ancestor, an inward " shift " towards the mean of the two grandparents having occurred similar to that described for glume-length (p. 396).

The length of the grains of the extracted homozygote *polonicum* of F_2 and F_3 was 13-14 per cent less than that of the original *polonicum* parent, the F_2 *durum* forms being about 8 per cent greater than those of the original *durum*.

Grain Colour.—In respect of colour, wheat grains are usually divided into the two classes red and white. In the former a reddish or brownish substance is present in the testa of the seed and absent from the seed-coat of white grains.

One or two Abyssinian varieties (pp. 195, 196) of wheat have purple-coloured grains, but in these the colour is due to an anthocyan pigment in the " chlorophyll " or " cross layer " of the pericarp.

i. *White* × *White*.—The usual result of crossing two white-grained wheats is the production of white-grained descendants in F_1 and all subsequent generations.

Vilmorin, however, obtained red-grained plants among the F_2 progeny of a hybrid between two white-grained forms of *T. polonicum* and *T. turgidum* (p. 397).

Pitsch also records the appearance of a few yellow- or reddish-grained plants in the sixth generation from the hybrid " Squarehead " × " Challenge," which he states were two white-grained wheats.

ii. *Red* × *Red*.—The progeny from this cross is generally red in all generations.

Tschermak, however, states that in some instances white-grained individuals have appeared among the descendants of hybrids between different red-grained varieties.

Nilsson-Ehle also records the occurrence of white-grained plants in F_2 of the hybrid " Bore " wheat × " Extra Squarehead," both red-grained parents.

He suggests that two independent and different factors for red (R_1 and R_2) are concerned, the respective uniting gametes being R_1r_2 and r_1R_2.

From such a cross, white individuals (r_1r_2) would appear in F_2, in the proportion of 1 white to 15 red.

iii. *Red* × *White*.—Very numerous investigations have been made regarding the hybridisation of red- and white-grained wheats.

Red dominates white, the F_1 generation being red-grained, but the grains are a paler tint than those of the red parent.

The segregation in F_2 depends on the character of the red parent. In a large number of instances the F_2 generation consists of red- and white-grained descendants in the proportion of 3 red : 1 white, the red tint being due to a single Mendelian factor.

Nilsson-Ehle discovered that the trihybrid ratio of 63 red : 1 white occurred in the F_2 generation when certain red wheats were crossed with white.

From the hybrid Svalöf "Pudel" ♀ (a white velvet-chaffed, white-grained Squarehead) × Swedish "Sammet" ♂ (a velvet-chaffed form with dark red grain) he obtained in F_1 plants with pale red grains. All the grains of the F_2 generation were also red, but of several shades. On raising the F_3 generation from one of these hybrids, he found that some of the plants segregated approximately in the ratio 3 red : 1 white; others gave a progeny of about 15 red : 1 white, while a smaller number exhibited the trihybrid segregation of 63 red : 1 white.

An analysis of the results led him to the conclusion that the red grain colour of the particular parent employed was dependent upon the presence of three dominant and independent factors R_1, R_2, and R_3, each of which by itself is capable of producing redness, the varying shades of grain tint among the progeny of the cross with a white-grained parent ($r_1r_2r_3$) in which these factors are absent, being brought about by the additive or cumulative action of the several colour factors. For example, where two or three factors are present in the zygote the red tint of the grain is twice or thrice the depth of colour of those of a plant into which only one has entered. Only when all the factors are present is the original dark red-tinted grain of the parent reproduced.

On this hypothesis the gametic constitution of the red parent is R_1R_1 R_2R_2 R_3R_3, that of the contrasted white parent r_1r_1 r_2r_2 r_3r_3. The sixty-four possible individuals and twenty-seven genotypes of the F_2 generation obtained from the cross $R_1R_2R_3 \times r_1r_2r_3$ may be arranged as shown in table on top of next page.

The number of red-producing factors entering into the various genotypes of the F_2 generation is indicated at the base of each column of the diagram; the frequency distribution of the numbers of individuals of the several tints of the population is that of a symmetrical polygon of fluctuating variation.

				$R_1r_1R_2r_2R_3r_3$ 63 : 1			
				Do.			
				Do.			
				Do.			
				Do.			
			$R_1r_1R_2R_2R_3r_3$ all red	Do.	$r_1r_1R_2r_2R_3r_3$ 15 : 1		
			Do.	Do.	Do.		
			Do.	Do.	Do.		
			Do.	$r_1r_1R_2r_2R_3R_3$ all red	Do.		
			$R_1r_1R_2r_2R_3R_3$ all red	Do.	$R_1r_1r_2r_2R_3r_3$ 15 : 1		
			Do.	$r_1r_1R_2R_2R_3r_3$ all red	Do.		
			Do.	Do.	Do.		
			Do.	$R_1R_1r_2r_2R_3r_3$ all red	Do.		
			$R_1R_1R_2r_2R_3r_3$ all red	Do.	$R_1r_1R_2r_2r_3r_3$ 15 : 1		
		$R_1r_1R_2R_2R_3R_3$ all red	Do.	$R_1r_1R_2R_2r_3r_3$ all red	Do.	$r_1r_1r_2r_2R_3r_3$ 3 : 1	
		Do.	Do.	Do.	Do.	Do.	
		$R_1R_1R_2r_2R_3R_3$ all red	Do.	$R_1r_1r_2r_2R_3R_3$ all red	Do.	$r_1r_1R_2r_2r_3r_3$ 3 : 1	
		Do.	$r_1r_1R_2R_2R_3R_3$ all red	Do.	$r_1r_1r_2r_2R_3R_3$ all red	Do.	
		$R_1R_1R_2R_2R_3r_3$ all red	$R_1R_1r_2r_2R_3R_3$ all red	$R_1R_1R_2r_2r_3r_3$ all red	$r_1r_1R_2R_2r_3r_3$ all red	$R_1r_1r_2r_2r_3r_3$ 3 : 1	
	$R_1R_1R_2R_2R_3R_3$ all red	Do.	$R_1R_1R_2R_2r_3r_3$ all red	Do.	$R_1R_1r_2r_2r_3r_3$ all red	Do.	$r_1r_1r_2r_2r_3r_3$ all white
No. of red factors in Zygote .	6	5	4	3	2	1	0
No. of Zygotes .	1	6	15	20	15	6	1

In F_3 the segregation of the sixty-four individuals of the F_2 generation should occur as follows :

	No. of Heterozygous Factors present.				
	4 or more.	3.	2.	1.	No Red Factors.
Segregation . .	Constant red	63 : 1	15 : 1	3 : 1	Constant white.
No. of individuals	37	8	12	6	1

Segregation of an F_2 generation tested by Nilsson-Ehle gave in F_3 the following proportional numbers :

	Constant red	63 : 1	15 : 1	3 : 1	White.
	37	8	12·3	6·6	1

which agree very closely with the expected figures.

In addition to "Pudel" wheat, Nilsson-Ehle found that the grain colour of Svalöf "Grenadier" wheat is a three-factor red.

Investigations showed that the grain tints of Extra Squarehead II., "Bore" wheat, and a pure line of Swedish *T. compactum* are two-factor reds, hybrids of these with white-grained wheats segregating in F_2 in the ratio 15 red : 1 white.

A. and G. Howard obtained similar evidence of the existence of double factors for red grain colour in some Indian forms of *T. vulgare* and of a three-factor red in *T. compactum*, var. *erinaceum* ("American Club").

iv. *Purple* × *White*.—Caporn studied the inheritance of the purple tint in a cross made originally by Biffen between *T. polonicum* with white translucent grain and the purple-grained Abyssinian wheat "*T. Eloboni*" (= *T. dicoccum*, var. *Arraseita* (p. 195)).

The F_1 grains were all uniformly purple. In F_2 were found (1) fully tinted or "flushed" grains of light and dark shades, (2) grains with longitudinal streaks of purple, and (3) uncoloured grains the proportions approximating to the ratio 3 flushed : 1 streaked : 12 uncoloured.

Some of the "streaked" plants bred true while others were heterozygous "streakeds" whose descendants exhibited the simple 3 : 1 monohybrid segregation.

The "uncoloured" plants appeared to be of two kinds, namely (*a*) those throwing "uncoloured" plants only, and (*b*) others giving "uncoloured" and "streaked" progeny, the approximate ratio of *a* : *b* being 15 : 1.

Segregation similar to that occurring in F_2 was not found in F_3; other complicated results requiring further study for elucidation were met with in the F_3 generation.

Flinty and Mealy Endosperm.—The inheritance of these characters is complicated by the fact that their appearance is largely dependent upon external conditions of soil and climate.

The flinty character is stated by Biffen and Tschermak to be dominant, but further investigation of the matter is desirable.

Susceptibility and Resistance to the Attacks of Rust-fungi (*Puccinia* sp.).—The variable incidence of the attacks of Yellow Rust (*Puccinia glumarum*, Er. et Henn.) is strikingly evident almost every year on examining the collection of wheats at Reading in spring.

Upon *T. aegilopoides* and *T. monococcum* the rust is never found, and several forms of *T. dicoccoides*, *T. dicoccum*, *T. durum*, *T. turgidum*, and *T. vulgare* are usually nearly free from the parasite. A larger number of forms of the same races are slightly attacked, while many forms of *T. vulgare*, especially those from India, Persia, and Central Asia, are so

severely infected that the upper parts of the young leaves are covered almost entirely with the bright yellow sori of the fungus, and the surface of the soil around the plants is bright yellow with the fallen uredospores.

Although the extent of the attack on the different wheats varies from year to year, the classification into resistant and susceptible forms is easy, and infection or freedom from attack are found to be constant hereditary characters.

It was Biffen who first investigated the inheritance of resistance and susceptibility to the attacks of *P. glumarum*, and discovered that these characters form a Mendelian allelomorphic pair. On crossing resistant forms of *T. turgidum* (Rivet), *T. compactum* (American Club), and *T. vulgare* (Hungarian Red) with very susceptible forms of *T. vulgare* (Michigan Bronze, Preston, and Hungarian White) susceptibility was found to be a dominant character, the hybrid F_1 generation being as easily attacked as the susceptible parents.

In F_2 immune and susceptible segregates were obtained in the proportion of 3 susceptible to 1 resistant, which bred true in the F_3 generation, immunity proving a recessive character.

While the immune or resistant forms were not completely free from attacks of the rust, they could be distinguished without much difficulty from the susceptible plants.

Among the infected segregates there appeared to be different degrees of susceptibility, and the plants in the F_3 bred more or less true to the variable character. Later Nilsson-Ehle also examined the inheritance of the same species of rust in hybrids between more or less susceptible and resistant forms of *T. vulgare*. He confirmed Biffen's results, but observed that well-marked dominance of susceptibility was rarely found, the F_1 being intermediate.

In the F_2 generation segregation was evident, but the establishment of definite numerical ratios was not possible, the segregates being finely graded between those which might be classed as resistant and the most susceptible plants. Moreover, in some of the crosses transgressive segregation occurred in F_2, plants more susceptible and more resistant than either of the grandparents being found in this and subsequent generations.

Biffen also observed plants more susceptible than either of the grandparents in the F_2 generation of the hybrid Rivet × Red Fife.

Nilsson-Ehle attributes these results to the existence of multiple factors for the susceptible and resistant characters (cf. inheritance of grain colour, pp. 373-375).

The researches of Pole-Evans in South Africa regarding the inheritance of susceptibility and resistance of wheats to the attacks of Black Stem-rust (*Puccinia graminis*, Pers.) show that susceptibility is the dominant, resistance the recessive character as in *P. glumarum*. In the

FIG. 219.

1. *T. aegilopoides*, var. *Larionowi*. 2. Hybrid (F_1) of 3 ♀ × 1 ♂. 3. *T. dicoccum*, var. *farrum*.

cross Bobs × Wol Koren the hybrid F_1 proved to be considerably more susceptible than the susceptible Wol Koren parent.

Hayes, Parker, and Kurtzweil also investigated the susceptibility to *P. graminis* of hybrids of wheats belonging to the races *T. vulgare*, *T. durum*, and *T. dicoccum*.

The susceptible *vulgare* wheats used were Preston, Marquis, and Pioneer, the *durums* Kubanka and three other resistant forms, in addition to a form of *T. dicoccum* (White Spring Emmer), being used as the second parents.

In the F_1 of the *vulgare* × *durum* crosses susceptibility was dominant, and in some of the F_2 and F_3 generations transgressive segregation occurred, a few plants being more susceptible or more resistant than either of the grandparents.

In the *vulgare* × *dicoccum* hybrids susceptibility was recessive. There was also evidence of linkage of the *durum* and *dicoccum* characters and resistance to rust.

I. Hybrids of the Wild Wheats *Triticum aegilopoides* and *Triticum dicoccoides* with each other and with Species of *Aegilops* and Rye

1. *T. aegilopoides* × *T. dicoccoides*.—The wild wheats *T. aegilopoides* and *T. dicoccoides* are very frequently found growing near each other in various parts of Syria and Palestine, and transitional forms between these were observed by Aaronsohn. Whether these intermediates were the products of natural hybridisation or varietal forms of the wild wheats was not determined.

From a study of the glume characters Schulz considers that some of the specimens sent by Aaronsohn to Germany as *T. dicoccoides* were hybrids of *T. aegilopoides*, var. *Thaoudar*, and *T. dicoccoides*.

I am inclined also to the view that some of the wild wheats which I received from the eastern side of Mount Hermon were hybrids, the empty glumes having the characteristic lateral tooth of *T. aegilopoides*, while the size and general features of the ear as well as the vegetative characters of the plants were those of *T. dicoccoides*.

2. *T. dicoccoides* × *Aegilops ovata*.—Cook refers to the discovery in Syria of a supposed hybrid between the wild *dicoccoides* and *Aegilops ovata*, the plant exhibiting intermediate characters of ear, rachis, and awns. Aaronsohn considered it a hybrid between the two species, and the figure of the spikelets given by Cook is suggestive of the cross.

Tschermak, in his papers on "Rare Cereal Hybrids," states that he crossed *T. dicoccoides* with *Aegilops ovata* and also with *Aegilops cylindrica*, using the wild wheat as the maternal parent. The hybrids were sterile.

3. *T. dicoccoides* × *Secale cereale*.—Tschermak states that Jesenko crossed the wild *T. dicoccoides* with rye and found the hybrid sterile.

II. Hybrids of the Wild Wheats *T. aegilopoides* and *T. dicoccoides* with Cultivated Wheats

1. *T. aegilopoides* × *T. dicoccum.*

(*a*) *T. aegilopoides* ♀ × *T. dicoccum* ♂.—Beijerinck records the crossing of these two species, the female parent being a winter black-chaffed variety of *T. aegilopoides* (*T. nigrescens* of Pantčic or *T. aegilopoides*, var. *Pančici*), the male being the strong-growing form of *T. dicoccum*, var. *farrum* (p. 197).

The F_1 plants were quite sterile and had ears 18 cm. long each with 38-40 spikelets. The rachis was hairy and very brittle, like that of the female parent, the form of the empty glumes resembling that of the male.

(*b*) *T. dicoccum*, var. *farrum* ♀ × *T. aegilopoides*, var. *Larionowi* ♂ (Fig. 219).—I successfully crossed these two wheats in 1917. The hybrid (F_1) plant was completely sterile and exhibited characters of both parents. In length and arrangement the hairs on the upper surface of the young leaves resembled those of the mother. The ears were fragile, intermediate in breadth and thickness between the two parents, with reddish empty glumes like those of the pollen parent, but similar in form and terminating in an incurved apical tooth like those of *T. dicoccum*.

The base of the spikelets and edges of the rachilla were as hairy as those of *T. aegilopoides*, and the flowering glumes terminated in long awns like those of the latter plant.

2. *T. dicoccoides* × with Cultivated Wheats.—In his paper on "Rare Cereal Hybrids" Tschermak states that *T. dicoccoides* crosses with *T. monococcum*, *T. dicoccum*, *T. durum*, and *T. Spelta*, but gives no descriptions.

The wild *T. dicoccoides* crosses readily with *T. vulgare* and *T. durum*. Natural hybrids of these occur in Palestine and Syria and are frequently obtained when the cultivated races are grown in the garden in proximity to the wild species; in fact, it is difficult to preserve a pure line of *T. dicoccoides* where other wheats are grown.

In the cross made by Tschermak between *T. dicoccoides* and *T. vulgare* the F_1 plant closely resembled the wild species. In F_2 appeared *T. dicoccoides* and a mixture of *T. dicoccum*, *T. durum*, *T. vulgare*, and *T. Spelta*.

I have also frequently observed the similar production of a variety of forms of *T. dicoccum*, *T. durum*, *T. Spelta*, and *T. vulgare* in the F_2 generation from natural hybrid F_1 plants found in pedigree rows of *T. dicoccoides*.

The following is an example of the great diversity exhibited among the segregates of these sporadic hybrids (see Figs. 220, 221).

A single ear of *T. dicoccoides*, var. *Aaronsohni*, gave a natural hybrid from which were obtained the following forms in the F_2 generation :

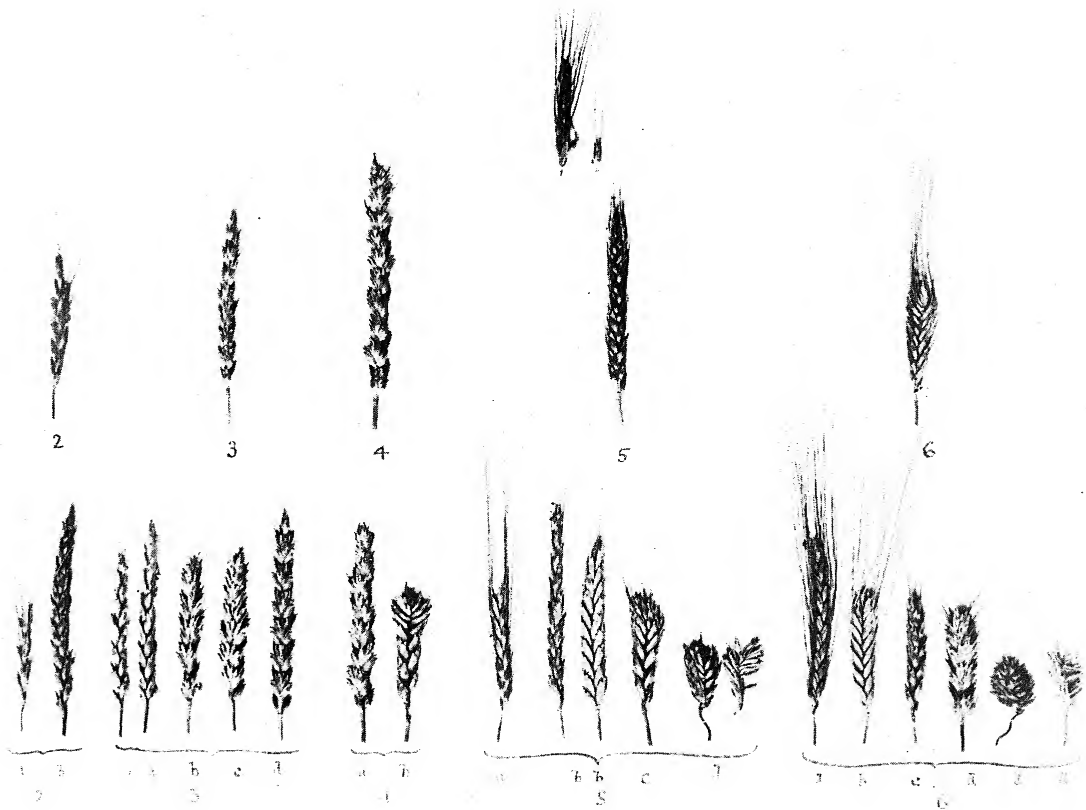
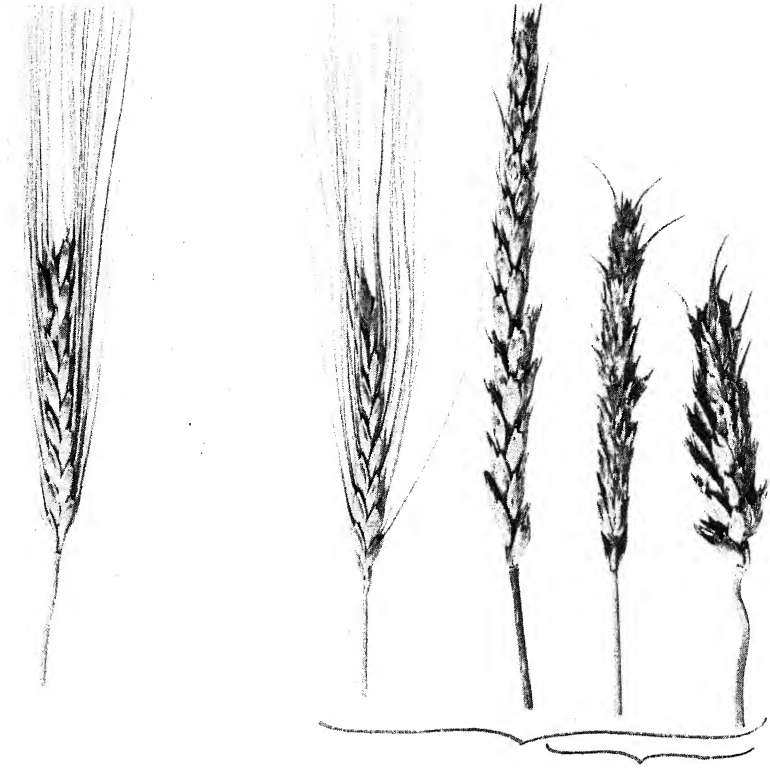


FIG. 220.—NATURAL HYBRID (*T. dicoccoides* ♀ × *T. vulgare* ♂ (?)).

2, 3, 4, 5, and 6 of the middle line are F_2 segregates.
2, 3, 4, 5, and 6 of the bottom line are the respective F_3 segregates from the ears above.



1 2 3 4 5

FIG. 221.—NATURAL HYBRID (*T. dicoccoides* ♀ × *T. vulgare* (?)).

2, 3, 4, 5. Segregates of the F_1 generation. 4 and 5 almost sterile.

1. Typical *dicoccoides*.
2. A *dicoccoides*-like form with short awns.
3. A beardless form resembling *T. Spelta*.
4. A long-eared *T. vulgare*.
5. A form with characters of *T. dicoccum* with short awns.
6. A dense-eared *durum*-like form.

The F_3 progeny of these were:

From plant 1, only typical *dicoccoides*.

" " 2. (*a*) *dicoccoides* (red-chaffed).
(*b*) semi-bearded forms approximating to cultivated *T. dicoccum* with non-hirsute rachis, some with red chaff, others with white chaff.
(*c*) sterile, beardless *T. vulgare*, dark brown chaff.

" " 3. (*a*) beardless *Spelta*-like forms, white-chaffed.
(*b*) sterile, beardless, red-chaffed *vulgare*.
(*c*) fertile, beardless, white-chaffed *vulgare*.
(*d*) fertile, beardless, red-chaffed *vulgare*.

" " 4. (*a*) beardless, lax-eared, red-chaffed *vulgare*.
(*b*) beardless, dense-eared, white-chaffed *vulgare*.

" " 5. (*a*) *T. dicoccoides* (red-chaffed).
(*b*) beardless, *dicoccum*-like forms, white- and red-chaffed, with smooth or hirsute rachis.
(*c*) beardless, red-chaffed and white-chaffed sterile *vulgare*.
(*d*) beardless, dense-eared, sterile, *durum*-like forms, some of them "freaks."

" " 6. (*a*) black-chaffed and red-chaffed *dicoccoides*.
(*b*) a long-awned sterile *durum*.
(*c*) beardless *dicoccum*-like forms, some with hirsute, others with glabrous rachis.
(*d*) several beardless, dense-eared *durum* and *vulgare* "freaks." Most of them sterile.

In morphological characters the glumes are very variable, and among the segregates resembling the cultivated wheats there is an almost continuous series of intermediates between completely sterile forms and those with all the spikelets fertile. While the majority possess easily disarticulated ears, there are many with various degrees of brittleness of the rachis and similar diversity in the habit of growth and time of ripening of the several forms.

In general characters these segregates resemble those obtained by Tschermak, who states that the F_2 generation of a hybrid between *T. dicoccoides* and *T. vulgare* gave a mixture of *T. Spelta*, *T. dicoccum*, *T. vulgare*, and *T. durum*.

Some of the progeny including the dense-eared "freaks" are singu-

larly like the descendants of a cross between a "mutation from Black Emmer" (*T. dicoccum*, var. *atratum*) and a beardless mutation from the bearded Turkey red wheat (*T. vulgare*, var. *ferrugineum*) recorded and figured by Buffum.

Although all the four races of cultivated wheats mentioned are generally seen among the descendants of these natural hybrids, the relative proportion of the several races is not always the same; in the one described there is a preponderance of fertile *vulgare* forms, but in others fertile *durum* forms predominate; the former are presumably crossed with *T. vulgare*, the latter with *T. durum*.

Love and Craig observed the occurrence of forms very closely resembling Wild Emmer in brittleness and hairiness of rachis, form of spikelets and glumes, and shape and size of grain among the segregates in F_2 and F_3 of a cross between Early Red Chief (*T. vulgare*, var. *milturum*) and Marouani (*T. durum*, var. *leucomelan*).

III. Hybrids of Cultivated Wheats with Wild Grasses

1. Wheat × Couch Grass.

Triticum vulgare ♀ × *Agropyrum repens* (Beauv.) ♂.—Hillman figures a hybrid between these species and the resulting progeny obtained by Fr. Strube, but no descriptions are given. He also refers to a similar hybrid exhibited by G. Bestehorn. Further evidence is necessary before the hybridisation of these plants can be accepted.

2. Wheat × Italian Rye Grass.

Triticum vulgare ♀ × *Lolium italicum* (A. Br.) ♂.—Schliephacke mentions the production of a sterile hybrid from the crossing of wheat with Italian Rye Grass, and gives a figure of the ear of the hybrid plant without any description. The figure resembles that of a wheat × rye hybrid, which is also illustrated in the same communication. The evidence for the crossing of these species is inconclusive.

3. Wheat × Various Species of *Aegilops*.

(*a*) (i.) *Aegilops ovata* ♀ × *Triticum vulgare* ♂ = *Aegilops triticoides* (Req.), Bertoloni.—This hybrid is of much interest since it was the first wild hybrid grass whose origin was determined by experiment, and its discovery incidentally led to a great pre-Darwinian discussion among botanists in Europe and America regarding the fixity of species and the origin of cultivated wheats. Requien first collected the plant in 1821–24 around Avignon and Nîmes in the south of France, and on account of its resemblance to cultivated wheat he named it *Aegilops triticoides*. He published no account of it, but Bertoloni, acknowledging Requien's name, described the plant in his *Flora Italica* (vol. i. p. 788), and on the authority

of Gussone and Tenore recorded its occurrence in Sicily. It has since been found in Algeria.

Aegilops triticoides (Figs. 222, 223) is a rare sporadic plant, generally quite sterile, with tall erect culms 50-90 cm. high, bearded or semi-bearded, cylindrical ears 8-10 cm. long, consisting of 6-10 or more spikelets, each possessing two flowers. The empty glumes are flatter than those of other species of *Aegilops* and distinctly keeled, with only one or two awns and rudiments of others. When ripe the ear disarticulates near its base and falls to the ground (Fig. 223).

Aegilops ovata is a common species in all the countries bordering on the Mediterranean. It has somewhat decumbent stems 20-30 cm. long and short ears about 4 cm. long. The latter usually possess two fertile spikelets, each containing a pair of grains when ripe, the base and apex of the inflorescence being composed of a few degenerate spikelets or spikelets with staminate flowers only.

The empty glumes which almost cover the rest of the spikelet are ventricose, rounded on the back, without any distinct keel, but possessing a number of prominent nerves; at the apex are 4 awns (Fig. 223).

When the ear is ripe it disarticulates below the first fertile spikelet, and after falling to the ground becomes buried in the soil, where its grains, tightly enclosed in the glumes, germinate and give rise to a tuft of three or four closely knitted but independent plants.

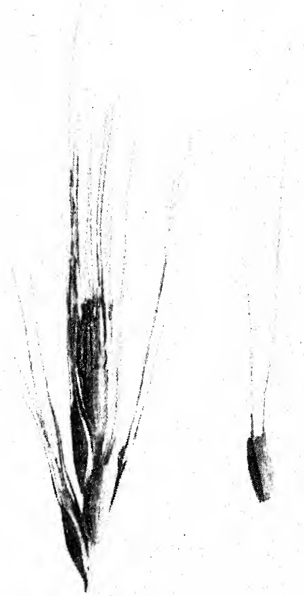


Fig. 222.—Ear of *Aegilops triticoides* and empty glume (nat. size).

In 1838 Esprit Fabre, a gardener living at Agde, near Montpellier, observed that although the grains of *A. ovata* usually give rise to plants like the parent, in some rare instances plants of *Aegilops ovata* and *Aegilops triticoides* are found growing from grains of the same ear. The fact of two strikingly different plants springing from separate grains of the same inflorescence attracted the attention of botanists, and its bearing on the fixity of species was widely discussed.

Fabre cultivated *A. triticoides* for about twenty years, at first in an enclosed garden, and subsequently in open fields, and found that the plants in successive seasons became more and more like Bread Wheat (*Triticum vulgare*).

At first almost sterile and sparing in yield of grain during the first three or four years, they became by degrees more fertile, the ears lost much of their brittle character, increased in length, and the number of flowers in the spikelets rose from 2 to 4 or 5.

The empty glumes lost the broad, symmetrical, convex form of those of the original mother plant, becoming longer, carinate, and unsymmetrical like those of wheat, and the number of awns decreased from 4 to 1 with mere rudiments of others (3, Fig. 223).

Aegilops ovata never appeared among the descendants, and the latter in seven or eight years were indistinguishable from ordinary cultivated wheat of the district, having tall stiff straw and ears with 8-12 spikelets, each bearing 2-3 fertile grains.

From his observations and experiments Fabre concluded that *Aegilops triticoides* was a sport of *A. ovata*, which under cultivation was gradually transformed into ordinary wheat, and that all wheats had their origin in *Aegilops ovata*.

Fabre's facts were confirmed by others, but his conclusions were the subject of dispute for a long time.

Regel appears to have suggested that *A. triticoides* was possibly a hybrid, but it was Godron who first experimentally established the hybrid nature of Requien's species. This botanist, in 1853, scattered the pollen of a beardless form of wheat (Touzelle) on six ears of *A. ovata* about the time of anthesis; from five of these ears only typical plants of *A. ovata* were raised, but one grain of the sixth inflorescence produced a short-awned form of *A. triticoides*. Later (in 1859) he sowed wheat in the Botanic Garden at Nancy, in rows 50 cm. apart, and planted ears of *A. ovata* between them. In 1860 he collected 872 ears from the *Aegilops* plants; these he put in the soil in February 1861, and from them were produced twelve plants of *A. triticoides* in July. He obtained similar natural hybrids in his own garden in 1870 and 1871 from *A. ovata* exposed to the pollen of wheat plants growing near.

The artificial production of *A. triticoides* was carried out by Godron in 1853. Two flowers of an ear of *A. ovata*, after careful emasculation, were pollinated with pollen from a bearded *vulgare* wheat; from these *A. triticoides* was raised, the remaining close-pollinated flowers of the same ear giving rise to plants of *A. ovata*.

Regel, Groenland, and Planchon also produced the hybrid by carefully controlled artificial crossing of *A. ovata* with beardless forms of *T. vulgare*.

A. triticoides in a wild state is nearly always sterile, never abundant, and always sporadically distributed in the neighbourhood of wheat fields, having long awns in the districts where bearded wheats are cultivated (Fig. 222), and short awns where beardless wheats are grown (2, Fig. 223).

FIG. 223.

1. *Aegilops ovata*, L., with empty glume and grains. 2. *Aegilops triticoides* (Req.), Bertol.
3. *Aegilops speltaeformis*, Jord., with spikelet, empty glume, and grain.

These facts, together with the experimental results of Godron and others, make it clear that the so-called wild "sports" or varieties of *A. ovata* from which Fabre began his cultivations were natural hybrids, the result of chance fertilisations of *A. ovata* by pollen of wheat from neighbouring fields.

Godron found that the first cross is sterile, due to the imperfection of the stamens, but, as discussed later, it yields secondary hybrids with pollen of its male parent (*T. vulgare*).

Bally, in 1916 and 1917, made the cross *T. vulgare* ♀ × *Aegilops ovata* ♂ and obtained 3 F_1 plants from some 40 pollinations. He succeeded also with the reciprocal cross *Aegilops ovata* ♀ × *T. vulgare* ♂, obtaining 2 F_1 plants from about 200 pollinations.

In both cases the hybrids were alike and sterile, and resembled those obtained by Godron and others. The pollen grains varied considerably in size, fluctuating between 20 and 53 μ in diameter; they were more translucent than those of either parent, and devoid of the fine starch grains seen in the normal pollen grains of wheat and *Aegilops*. Bally also studied the cytology of the two parents and the hybrid, and found that the haploid number of chromosomes in wheat is 8, that of *Aegilops* 16. The hybrid presumably should have 12 $\left(=\frac{8+16}{2}\right)$ as the haploid number. In some cases he found this number present, but in others the number was greater than 12, for during the reduction division some of the *Aegilops* chromosomes remained unpaired and divided longitudinally as in the ordinary homotypic mitosis. The wheat chromosomes are short and thick, those of *Aegilops* much longer and thinner. In the meiotic division of the hybrid the two parental chromosomes which can be recognised with certainty travel to the poles of the spindle at different rates, the wheat chromosomes reaching the poles while those of the *Aegilops* parent are still in metaphase.

In addition to the irregular meiotic division, abnormalities occur in the formation of the pollen tetrads, which result in the production of multinucleate pollen grains, containing from 2 to 4 nuclei of very variable size and chromosome constitution.

(ii.) (*Aegilops ovata* ♀ × *Triticum vulgare* ♂) × *Triticum vulgare* ♂ = *Aegilops triticoides* ♀ × *Triticum vulgare* ♂ = *Aegilops speltaeformis*, Jordan.—A fierce controversy arose among botanists regarding *Aegilops triticoides* and its transformation into ordinary wheat, the polemic being most actively maintained for several years by Jordan and Godron.

Jordan with his metaphysical and inflexible views on the immutability of species at first disbelieved the facts described by Fabre, Godron, and others. He was, however, ultimately constrained to admit that *A. triticoides* is a sterile sport or "deformation [of *A. ovata*] due to hybridisation."

In regard to the fertile wheat-like plants obtained and cultivated by Fabre on an extensive scale he held a novel opinion. Their fertility and morphological stability over twenty or more generations led him to conclude that these were not of hybrid origin, but the descendants of a new, rare, and unrecorded species of *Aegilops*, distinct from *A. triticoides*, but easily confused with it.

To this imaginary species he gave the name *A. speltaeformis*, and suggested that it had found its way unobserved into the south of France from the East along the Mediterranean.

The plant is annual, with broad, flat, green, or glaucescent leaves, similar to those of ordinary wheat. The straw is from 60 to 100 cm. high, with an erect rigid ear, which when ripe falls off as a whole. The ears are about 10 cm. long (3, Fig. 223), consisting of 10-12 somewhat inflated flowered spikelets, 2 or 3 of the flowers frequently fertile. The empty glume is keeled, truncate, with an awn 3-4 times as long as the glume and usually 2 lateral teeth of variable length. The flowering glume is obtuse, truncate, with an awn 4 times as long as the glume and 2 short lateral teeth. The grain is oblong, oval, brownish, and angular with a deep furrow.

A. speltaeformis has rarely, if ever, been found wild either in France or in the East, and Godron's view that it is a derivative hybrid produced by the pollination of the sterile hybrid *A. triticoides* with wind-borne pollen of wheat has been generally accepted. Its non-establishment in a wild state Godron explains by the fact that its fallen ears and spikelets have not the power of burying themselves in the ground like those of *A. ovata* and *A. triticoides*, and soon perish after germination unless artificially covered with soil.

Godron states that Fabre obtained grains from ears of *A. triticoides*, which produced the very different and more robust *A. speltaeformis*. Groenland also grew the latter plant from a grain of an ear of *A. triticoides* gathered on the edge of a field near Agde by Dr. Thevenau.

The derivation of *A. speltaeformis* by artificial crossing of *A. triticoides* with wheat was proved by Godron in 1858, and again in 1860, but the cross is apparently very difficult, for no other botanist has been successful with it, failures being recorded by Regel, Tschermak, and Bally.

Some of the hybrids are completely sterile, others ripen a few grains, from which more fertile plants arise; these in turn ripen more grain in succeeding generations, until plants are obtained completely fertile and indistinguishable from ordinary wheat.

The increasing fertility and closer resemblance to wheat in succeeding generations observed by Fabre and by Durieu de Maisonneuve, who continued its cultivation without interruption for twenty-two years, has been

presumed hitherto to be due to successive annual fertilisation by wind-borne pollen.

It is possible, however, that the later generations are self-fertile, and that their increasing resemblance to ordinary wheat is brought about by the elimination of the *Aegilops* chromosomes in the abnormal heterotype divisions which Bally found in the primary hybrid *A. triticoides*.

In these irregular divisions the wheat chromosomes sometimes collect at the poles of the spindle before the *Aegilops* chromosomes leave the equatorial position, and in some of the pollen-grains nuclei may form which contain only wheat chromosomes, the *Aegilops* chromosomes or fragments of them appearing distributed within the cytoplasm of the cells, where they probably degenerate or enter into the formation of dwarf nuclei, which take no part in the fertilisation process when such grains are transferred to the stigmas of wheat flowers.

(*b*) *Aegilops triaristata*, Willd. ♀ × *Triticum vulgare* ♂ (= *A. triticoides*, Req.).—Planchon crossed these two species, and Fabre states that examples of *A. triticoides* arise from individual grains of fallen ears of *A. triaristata* as well as from *A. ovata*; thus the name *A. triticoides* is used for two different hybrids.

Inflorescences of the hybrid from *ovata* have the glaucous character of the mother with somewhat closely packed spikelets; those from *triaristata* are non-glaucous like the mother plant, and yellowish sometimes becoming dark brown when ripe, with the spikelets more distant from each other on the rachis.

(*c*) *A. ovata* ♀ × *T. Spelta* ♂ (Bearded Form).—Godron records the production of two examples of this hybrid, but gives no description of them. Groenland also obtained the same hybrid which was sterile.

(*d*) *A. ovata* ♀ × *T. turgidum* ♂.—Groenland obtained five samples of this hybrid; they produced a few grains in the first and second years, but became quite sterile and died out in the third season.

(*e*) *A. triaristata* ♀ × *T. durum* "*barbatum*" ♂.—A long-bearded hybrid was produced but not described by Godron.

(*f*) *A. ovata* ♀ × by all the different races of wheat.

A. cylindrica ♀ × by all the different races of wheat.

T. Spelta ♀ × *A. ovata* ♂.

T. Spelta ♀ × *A. cylindrica* ♂.

These hybrids were obtained by Tschermak: all were sterile, and attempts to cross them with the wheat or *Aegilops* parents failed.

(*g*) *A. triuncialis* ♀ × *T. vulgare* ♂.—Loret discovered this hybrid wild in the south of France.

(*h*) *A. ventricosa* ♀ × *T. vulgare* ♂.—This hybrid was produced by Vilmorin and Groenland: it is quite sterile. Henslow also obtained a

sterile hybrid among his cultivations of *A. ventricosa* which he thought was due to crossing with *T. turgidum*.

IV. Hybrids of Cultivated Wheats with Barley and Rye

1. Wheat × Barley.—It is frequently stated that the Australian wheat "Bobs" (p. 290) is a descendant of a hybrid between a sport from Blount's Lambrigg wheat (a form of *T. vulgare*, var. *albidum*) pollinated by William Farrer in 1896 with Nepal Barley or Bald Skinless barley, a six-rowed form with nude grains.

Farrer operated on a dozen flowers of the wheat, taking the usual precautions to prevent self-fertilisation. A single shrivelled seed was obtained which gave rise to an F_1 with somewhat light green foliage and weak straw suggestive of barley. The F_2 generation showed no evidence of F_2 parentage, but small differences were visible among the several plants from which "Bobs" appears to have been selected about four years after the original cross.

Mr. J. T. Pridham attempted the cross Fife wheat ♀ × Nepal barley ♂ but without success. From the reciprocal cross (Nepal barley ♀ × Fife wheat ♂), however, he obtained 7 grains; the F_1 plants from the latter when young had narrow, somewhat dark green, wheat-like leaves, but these characters disappeared as the plants grew, the adult plant having the broad light green leaves and ears exactly like the barley mother.

Mr. Pridham also tells me that Federation wheat was crossed with a 2-rowed naked barley. The F_1 of the Wheat ♀ × Barley ♂ cross had pale green foliage and very weak straw, like the barley parent, the reciprocal F_1 having narrower, darker, more wheat-like leaves. "In both cases," he says, "the F_2 progeny showed variations, such as the crossing of two not very distinct varieties would show in the variable generation, but no resemblance to barley that could be seen." There appears to be some justification for the belief in the greater than normal variability in these "crosses," and it is possible that the stimulus of the foreign pollen may be connected with its manifestation, but the evidence for the hybridisation of wheat and barley is inconclusive, and Farrer himself gives reasons for uncertainty in regard to the matter.

2. Wheat × Rye.

i. *T. monococcum* × *Secale cereale*.

ii. *T. polonicum* × *Secale cereale*.

Tschermak states that he crossed these two species of wheat with rye, the resulting hybrids being sterile. No descriptions are given in his paper.

iii. *T. vulgare* × *Secale cereale* (Fig. 224).

The artificial hybridisation of wheat and rye appears to have been

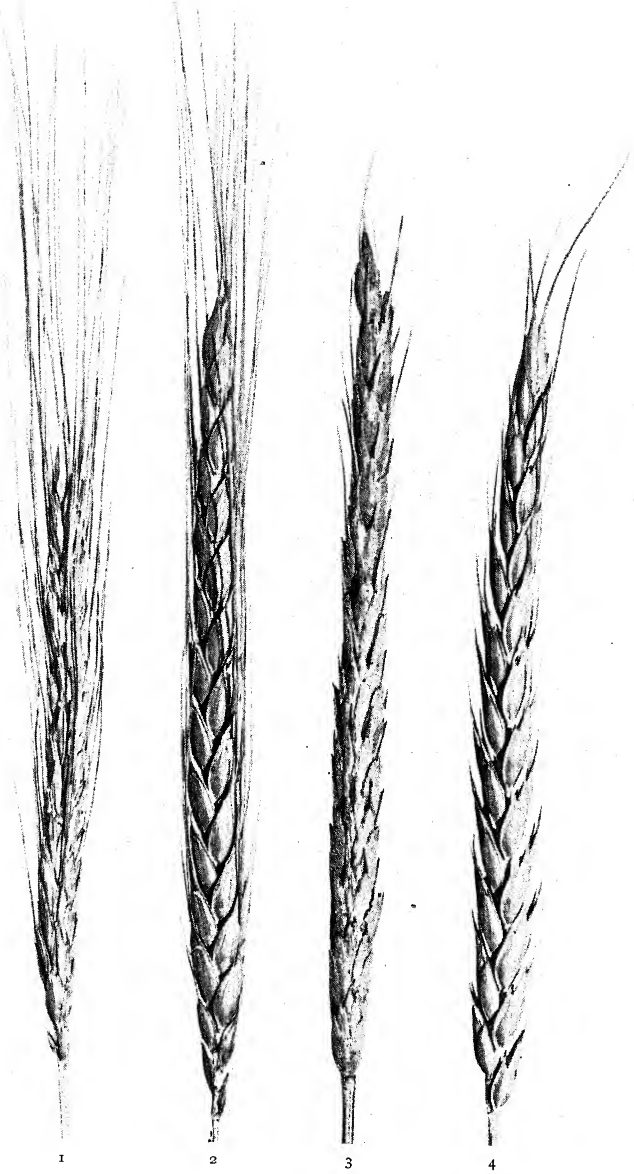


FIG. 224.—HYBRIDS OF WHEAT (*T. vulgare*) ♀ × RYE (*Secale cereale*) ♂.

1, 2, 3. Natural hybrids. 4. Artificial hybrid. (All from C. E. Leighty.)

first accomplished by A. S. Wilson, who recorded in 1875 the production of a sterile hybrid from the pollination of wheat with rye. Since that date similar successful crosses have been described or figured by Carman, Bernard, Rimpau, Signa, Schliephacke, Miczynski, Tschermak, McFadden, Ito, Jesenko, Leichty, and Backhouse. Nilsson-Ehle has twice observed natural hybrids between winter wheat and winter rye.

With the exception of Jesenko's hybrids with the wild *Triticum dicoccoides* and Emmer (*Triticum dicoccum*) all the work has been carried out with Bread Wheat (*T. vulgare*) and rye.

The cross only succeeds when wheat is made the mother plant, and then only with difficulty.

Jesenko pollinated more than 3500 flowers of rye with wheat pollen without the production of a single fertile grain; the reverse cross, however, he found effective on an average of about six times per 1000 pollinations as indicated in the following results of trials in 1909–1912.

In 1909, 580 flowers on 18 ears yielded 1 hybrid grain.
In 1910, 339 flowers on 12 ears yielded 0 hybrid grain.
In 1911, 3060 flowers on 102 ears yielded 29 hybrid grains.
(1 ear yielded 12.)
In 1912, 2150 flowers on 70 ears yielded 5 hybrid grains.

Similarly, Leighty obtained no result after 80 pollinations of rye with wheat, and only 3 grains from 172 pollinations of wheat with rye pollen. Backhouse also found the crossing of wheat and rye difficult except in the case of a Chinese beardless variety of *T. vulgare*, which he states set 32 out of 40 flowers pollinated with rye.

Jesenko discovered that the rye pollen germinates on the stigma and penetrates the style of the wheat gynaecium, probably reaching the micropyle of the ovum in the majority of cases, but the union of the sperm with the ovum is prevented, or the cross-fertilised ovum ceases to develop.

In some instances grains containing a small amount of endosperm were obtained apparently as the result of fertilisation, but these refused to germinate, the embryo being missing or imperfectly formed.

The hybrid plant exhibits the blended inheritance of both parents, with the rye-like characters perhaps more conspicuous than those of wheat.

When young, the F_1 plants resemble wheat in having a green coleoptile and well-developed auricles on the leaves, but the culms and leaves of the fully developed plants are greyish green, or dark green like those of rye, and the upper internode, especially of the first and second straws, are more or less pubescent like those of most forms of the latter plant. The hybrids tiller extensively, and continue to produce shoots late in the season

in the manner suggestive of a perennial grass. In height and thickness the culms are intermediate between the two parents.

The ears are long and narrow, frequently longer and having more spikelets than either parent. The empty glumes are elongated, intermediate in width, strongly keeled to the base, and toothed or scabrid along the keel like those of rye, but they possess more than one nerve, and the spikelets are many flowered, like those of wheat.

The absence of beards and the pubescence of the glumes are dominant characters in these hybrids.

In Tschermak's experiments Squarehead, Theiss, and Banat wheats were used as the mother plants. Jesenko employed Loosdorf Bearded, Bokhara, Velvet Squarehead, Red Galician, Epp, and other kinds of wheat.

Although in general features all the hybrids closely resemble each other, the specific characters of the particular form of mother plant from which they are descended are clearly recognisable; but in cases where different forms of rye are used as the male parent, their influence is not visible.

At the time of flowering the glumes open widely, and usually remain separated from six to eight days. The anthers do not dehisce, and contain mostly shrivelled and imperfectly formed pollen grains of variable size, with occasional transparent round grains smaller than those of either parent.

Jesenko and Nakao found that the formation of the tetrads from the pollen mother-cells was irregular, each of the latter being sometimes divided into 3, 5, 6, or more degenerate cells.

According to Nakao the larger pollen grains of the hybrid have many more than the normal haploid number (8) of chromosomes of the parents, the smaller ones less.

In regard to the fertility of wheat × rye hybrids, Tschermak and Nakao found the F_1 quite sterile, and Jesenko obtained negative results from more than 3000 flowers pollinated with the hybrid pollen. Carman, however, harvested 19 grains from 10 ears of one of his F_1 hybrid plants, presumably self-pollinated, and from these grains obtained 14 F_2 plants with 107 very variable ears. Among the plants of the F_3 generation were some bearing ears 7 inches long, others with ears only 2 inches long or less. The form of wheat Rural New Yorker No. 6, still grown in the United States, is said to be a descendant of one of these wheat × rye hybrids.

Rimpau, in 1888, harvested fifteen grains from the F_1 plant of the cross Red Saxon "Landwheat" × Schlanstedt rye grown under a net near a hybrid wheat: it is not known whether they were the result of self- or cross-fertilisation. The F_2 generation, like that obtained by Carman,

was very variable, consisting of plants with glabrous stems and ears of "Squarehead" form, as well as others with more slender lax ears: some of the plants were quite sterile, while others yielded viable grain in varying amounts.

The descendants of Rimpau's hybrid were still grown in various localities in Germany in 1912, more than twenty generations after the original cross. Such plants are remarkably constant, and exhibit characters intermediate between the two parents. The ears are long and narrow, some bearded, others beardless, with strongly keeled scabrid, rye-like glumes, which open widely and remain separated some considerable time at the period of anthesis. Much of the pollen is deformed and sterile, and the ears set a few grains only, even when pollinated with wheat pollen. Miczynski also obtained a naturally fertilised F_2 generation.

More recently Love and Craig produced hybrids of wheat and rye, most of which were sterile in F_1 and in morphological characters resembled those obtained by other workers. Two of the hybrids, however, were fertile. One of them, resulting from the crossing of Dawson's Golden Chaff wheat (a beardless red-chaffed white-grained variety) with common rye, had brown glumes intermediate in colour between those of the two parents, and ciliate keels like those of rye.

The hybrid was not quite sterile. A single F_2 plant raised from it had ears with short awns and sharply keeled ciliated glumes like the rye parent.

Only one seed was obtained from the F_2. This gave rise to a more wheat-like plant (F_3) with much increased fertility. The succeeding generation (F_4) had wheat-like ears, some of them fully fertile, others almost sterile. The grains varied in form; and in respect of length of awn, colour of chaff and grain, there was much variation with apparent segregation in the simple Mendelian 3 : 1 ratio.

With the exception of the F_1 plants, none of the later generations showed any of the rye-like pubescence of the upper internode. The plants of the F_5 generation showed an increasing resemblance to wheat, although some of them exhibited traces of rye characters.

The true fertility of the F_1 wheat × rye hybrids obtained by Carman, Rimpau, Love and Craig cannot be decided with certainty, for it is possible that in these cases the generations after F_1 were the result of chance pollinations from neighbouring wheat plants; nevertheless, the negative evidence of Tschermak, Nakao, and Jesenko cannot settle the matter. It is probable that the fertility may be dependent upon the varieties of wheat and rye used in the cross.

Crossing the F_1 hybrid with one of the parents has been carried out by Carman and Jesenko. The former pollinated an ear of a F_1 wheat × rye hybrid with rye. From this he obtained 17 grains, from which 14 F_2 plants were raised, most of them sterile; the fertile plants crossed

again with rye gave an entirely sterile F_3 generation. Jesenko obtained only a single fertile grain from over 4800 pollinations of F_1 flowers with rye, but he was more successful when wheat pollen was used; in the latter case about 3 per 1000 pollinations produced viable grain.

Although these derivative hybrids (F_1 plants pollinated with wheat) more closely resembled wheat than rye, no two individuals were morphologically alike; some of them were quite sterile, while among the rest there was a great range of fertility, those most resembling wheat being most fertile.

Jesenko points out that such results must be due to differences in the genetic constitution of the egg-cells, since the pollen used was always the same. He suggests that the carriers of the hereditary characters of the parents are not equally distributed in the eggs of the F_1 plant, some receiving more of the wheat "plasma," some less, and in the fertilisation of an egg, containing much wheat "plasma" with the gamete of a wheat pollen grain, the resulting hybrid would more closely resemble wheat than would be the case where union takes place between a similar wheat gamete and an egg containing a smaller proportion of wheat "plasma." In the latter case the hybrid would be less like wheat and more inclined to be sterile like the original F_1 hybrid, which is half wheat and half rye.

V. Hybrids of the Different Cultivated Races of Wheat

All the cultivated races of wheat have been successfully crossed with each other. Those in which *T. monococcum* is a parent are completely sterile; the rest give fertile progeny, although the degree of fertility is very variable.

In the hybridisation of *T. durum*, *T. turgidum*, *T. vulgare*, and *T. Spelta*, Vilmorin observed forms of all four races among the descendants of hybrids between either of the two former and one of the two latter, from which he concluded that all these wheats had a common ancestor.

Tschermak obtained similar results in his experiments. Kezer and Boyack found *T. Spelta* among the F_2 segregates of the cross *T. dicoccum* × *T. vulgare* (p. 393), and *T. durum* appeared in the F_2 of the hybrid *T. dicoccum* × *T. sphaerococcum* which I produced at Reading (p. 392).

1. Hybrids of *T. monococcum* with other Wheats.—Hybrids of *T. monococcum* with *T. dicoccum*, *T. vulgare*, *T. durum*, *T. turgidum*, and *T. polonicum* have been obtained by various workers. Tschermak states that he successfully crossed *T. monococcum* with all cultivated wheats.

The hybrids are sterile and have the flat brittle ear, keeled glumes, and marked lateral nerve and tooth of *T. monococcum*, but show the influence of the other wheats in the larger ears, clearly developed terminal

spikelet, and the presence of two awns on each spikelet : crossing of the F_1 with the parent forms does not succeed.

a. (i.) *T. monococcum*, var. *flavescens* ♀ (Engrain double) × *T. dicoccum*, var. *farrum* ♂ (Amidonnier blanc).—This hybrid was obtained by Beijerinck in 1882 and its reciprocal a little later. Both were similar to each other and quite sterile ; the gynaecium was apparently perfect, but the anthers did not open or shed pollen. The leaves of the hybrid were yellowish-green, and the nodes of the stem hairy like those of *T. monococcum.*

In general appearance the ears were intermediate between the two parents ; the empty glume had a curved apical tooth, somewhat similar to that of the male parent, the characteristic lateral tooth of *T. monococcum* being very much reduced or absent.

(ii.) *T. dicoccum*, var. *pycnurum* ♀ × *T. monococcum*, var. *flavescens* ♂.—This hybrid was obtained by Vavilov, from whom I received specimens of the parents and the F_1 plant in 1914. The hybrid was sterile with ears intermediate in size between those of the two parents. In the glabrous polished surface and reddish colour of the glumes, as well as in the velvety surface of the leaves, it resembled the mother plant.

b. T. monococcum × *T. durum.*—Blaringhem obtained the hybrid *T. monococcum*, var. *vulgare* × *T. durum* (an Algerian form). Three hybrid grains were produced by the same ear.

The F_1 plants grew vigorously, their ears resembling those of *T. dicoccum.* One of the plants was completely sterile, the other two were semi-fertile.

The F_2 and F_3 generations of the latter consisted of plants with the vegetative characters and late-ripening habit of *T. monococcum.* Most of the ears were sterile and resembled those of *T. dicoccum* : the fertile ears had fewer spikelets and were more like those of *T. durum.*

Tschermak also obtained a hybrid between *T. monococcum* and *T. durum.*

c. T. monococcum × *T. polonicum.*

T. monococcum, var. *flavescens* ♀ × *T. polonicum*, var. *compactum*, Link ♂.

Blaringhem succeeded with this cross in 1913. From one cross-pollinated ear of *T. monococcum* seven shrivelled grains incapable of germination were obtained, while from another ear of a different plant of the same pure line growing near and pollinated at the same time seven viable well-developed grains were produced. In both cases the pollen parents belonged to the same pure line, but were different individuals.

Tschermak also obtained a hybrid between *T. monococcum* and *T. polonicum.*

d. T. monococcum × *T. turgidum.*—The hybrid *T. turgidum* ♀ × *T.*

monococcum ♂ was produced by Biffen in 1903. The F_1 plant was damaged by *Puccinia graminis* and did not flower. Tschermak obtained a similar hybrid.

e. T. monococcum × *T. vulgare.*—Cross pollinations of these two wheats were made without result by Vilmorin in 1880.

Tschermak records the production of a few grains from a similar cross in 1906 : the F_1 plants, however, do not seem to have been described.

In 1911, after some failures, Vavilov obtained a single shrivelled grain from the cross *T. vulgare*, var. *erythrospermum* ♀ × *T. monococcum*, var. *flavescens* ♂. The mother plant was an early, white, smooth-chaffed, bearded wheat with red grain, the pollen parent being the variety of *T. monococcum* known as " Engrain double."

The hybrid (F_1) was a well-developed plant with five stems about 80 cm. high, ripening about two months later than either of the parents. The ears were flattened and fragile, and the empty glumes strongly keeled with conspicuous lateral nerves as in *T. monococcum*, while the straw was hollow and the nodes glabrous as in *T. vulgare*. The plant was sterile. Its glumes separated and remained apart several days at the flowering period. The gynaecium and lodicules were apparently normal, but the stamens were small with non-dehiscing anthers containing very small, wrinkled, and transparent pollen-grains. *T. monococcum* is immune to rust fungi, but the hybrid was readily inoculated with Brown Rust (*Puccinia triticina*) and showed the dominant susceptibility of the maternal parent.

2. Hybrids of *T. dicoccum* with other Wheats.

a. T. dicoccum × *T. monococcum* (see p. 391).

b. T. dicoccum × *T. durum.* I have no records of this cross.

c. T. dicoccum × *T. polonicum* (see p. 394).

d. T. dicoccum ♀, var. *atratum* (Black Emmer) × *T. sphaerococcum*, var. *globosum* ♂ (Punjab Type 5).

Black Emmer has tall hollow straw, bearded flat ears, with blue-black pubescent glumes, red grain, and is a late variety ; the Punjab wheat is very early, and possesses very short, hollow straw, short square beardless ears, with pubescent glumes and white, flinty grain.

The hybrid which I obtained in 1917 had ears exactly like those of the *dicoccum* parent, so much so that it appeared as if no crossing had occurred. The F_2 generation consisted of a very varied series of red-grained *dicoccum* forms, some with black glumes like the grandmother and late, others of intermediate flowering period, with uniform white glumes, uniform red glumes, white glumes with black margins and red glumes with black margins respectively. In addition to the *dicoccum* forms, there appeared one or two plants of a typical *T. durum*, with glabrous

leaves, red glumes, white grain, solid straw, and the early habit of the male grandparent.

On account of the irregular development of the glume pigment in the homozygotes and the intergrading of glume colour among the heterozygotes, accurate classification by eye-inspection alone was impossible.

The F_3 generation showed, however, that the F_2 generation consisted of the following segregates :

T. dicoccum forms :

(1) Homozygous black glumes or blackish glumes with darker margins.
(2) Homozygous uniform white glumes.
(3) Heterozygous white glumes with black margins, splitting into 1 white : 3 grey or blackish glumes.
(4) Heterozygous uniform red glumes, splitting into 1 white : 3 red.
(5) Heterozygous red glumes with black margins, splitting into 1 white : 3 white with black margins : 1 red : 3 red with black margins.

T. durum form :

(6) Uniform red glumes.

Factors for black, red, and white glumes were present in the F_1, those for black and red being apparently brought in by the black-glumed Emmer parent, the allelomorphic pairs of the cross being black and red, and black and white respectively.

The original parental dwarf *sphaerococcum* type of ear and straw disappeared altogether in this cross, and was not recovered as a recessive in the F_2 or F_3 generations of the hybrid, its place apparently being taken by the *durum* form : the white colour of its grain was seen, however, in the *durum*, and the peculiar curved apex of its empty glumes was visible among the majority of the segregates of F_2 and F_3.

The factor for beardlessness was not dominant in F_1 of this cross, and its influence was only slightly seen in the F_2 and F_3 among a few of the heterozygous plants (No. 3 above) which had shorter awns than the normal *dicoccum*.

In all these forms pubescence was linked with the black character.

(*e*) The hybrid *T. vulgare*, var. *lutescens* (Fultz Mediterranean) × *T. dicoccum*, var. *atratum* (Black Emmer), obtained by Kezer and Boyack, had the flattened ears and the dark, adherent, keeled chaff of the Emmer parent. The ears were "beard-tipped" and non-glaucous, the latter character being found in the *vulgare* parent.

The F_2 generation was extraordinarily diverse, from sixty-two to sixty-five distinct forms appearing, among which were examples of *T. dicoccum*, *T. vulgare*, and *T. Spelta*. In outline, density, and other characters the ears were equally diverse, many being quite unlike either grandparent.

Numerous grades were found between long and short, and lax and compact.

The colour of the glumes was also very varied, some had white chaff, others black, but few or none were as black as those of the Emmer grandparent.

As in the previously described Black Emmer hybrid a number had red or brown glumes, and pubescence was linked with the black character.

Many plants were sterile or semi-sterile.

3. HYBRIDS OF *T. durum* WITH OTHER WHEATS.

a. T. durum × *T. monococcum* (see p. 391).

b. T. durum × *T. polonicum* (see p. 395).

c. T. durum × *T. vulgare*.

(i.) *T. vulgare*, var. *albidum* (Chidham d'automne) × *T. durum* (Ismaël Velvet Chaff).—The F_1 of this cross produced by Vilmorin in 1879 had square beardless ears with a few short apical awns.

The F_2 consisted of an extraordinary series of forms of *T. durum* and *T. vulgare*, some with long awns, others beardless: both lax- and dense-eared *vulgares* were obtained with examples of *T. compactum*, *T. turgidum*, and *T. Spelta*. None were like the original parents of the cross.

(ii.) *T. vulgare*, var. *milturum* (Early Red Chief) × *T. durum*, var. *leucomelan* (Marouani).—The F_1 of this cross made by Love and Craig was a *vulgare*-like form, " beardless " with short, apical, black awns and red grain.

In the F_2 generation, segregation in regard to both chaff colour and grain colour occurred in the proportion of 15 red : 1 white, the ratio of the " beardless " to fully bearded being 3 : 1. Among the 113 descendants were forms of *T. durum* and *T. vulgare*, and in addition, two typical plants of wild *T. dicoccoides* with flat ears, brittle rachis, long hairs at the base of the spikelet, and narrow, elongated grain: the proportion 113 : 2 (wild forms) suggests the trihybrid ratio 64 : 1. Some of the plants of this generation had ears with " reversed " awns, the empty glumes bearing very long beards, while the awns of the flowering glumes were quite short.

4. HYBRIDS OF *T. polonicum* WITH OTHER WHEATS.—Artificial hybrids have been obtained between *T. polonicum* and most of the other cultivated races of wheat. Several natural hybrids have also been observed.

With the probable exception of the cross *T. monococcum* × *T. polonicum*, the hybrids are fertile or semi-fertile.

a. T. monococcum ♀ × *T. polonicum* ♂ (p. 391).

b. T. polonicum ♀ × *T. dicoccum* ♂.—(i.) In 1916 I discovered a single hybrid ear (1, Fig. 225) among the progeny of a pedigree row of *T. polonicum*, growing in close proximity to pure lines of *T. dicoccum*. The *polonicum* parent had white papery chaff, 30-33 mm. long, slightly hairy on the nerves, and white flinty grain 10-11 mm. long. The

FIG. 225.—NATURAL HYBRID (*T. polonicum* ♀ × *T. dicoccum* ♂).
2, 3, and 4. Segregates of the F_2 generation.

dicoccum parent, I have no doubt, was a white-chaffed European form, with empty glumes about 10 mm. long, terminating in a curved apical tooth, and grain red and flinty, about 9 mm. long.

The F_1 ear was narrow, about 10 cm. long, with brittle rachis, white awns, and empty glumes about 15 mm. long, clothed with fine, adpressed hairs; the grains were dark red, flinty, and 9·5 mm. long.

The F_2 from this gave three clearly differentiated types, viz.:

(1) *T. polonicum*, almost typical in form and size of ear, with somewhat brittle rachis, thin, quite glabrous, empty glumes, 25 mm. long, and dark red flinty grain 10 mm. long.

(2) A form closely resembling the white-chaffed European *T. dicoccum*, with fragile rachis, stout empty glumes, finely pubescent, about 11 mm. long, with a strong, incurved, apical tooth, and dark-red flinty grain: some of the ears had fine black awns.

(3) An intermediate type with brittle ears, nearer in character to the *dicoccum* than the *polonicum* parent, the empty glumes quite glabrous, intermediate in texture, and 15-17 mm. long, ending in an intermediate incurved tooth, the grain 10 mm. long, dark red and flinty.

The types (1) and (2) bred true in the F_3 and F_4 generations: type (3) behaved as the F_1 plant. The young leaves of all the plants were pubescent like those of the *dicoccum* parent; none were glabrous like *polonicum*. Brittleness of ear and red grain were dominant, and the white grain of the *polonicum* parent did not reappear in the F_2 or F_3 generations.

(ii.) *T. polonicum* × *T. dicoccum*, var. *Arraseita* ("*T. Eloboni*").—This hybrid obtained by Biffen in 1913 was investigated by Caporn later.

The average glume-length of the *polonicum* parent was 29·23 mm., the glume-length of the *dicoccum* parent ranging between 8 mm. and 13 mm.

The F_1 plants had intermediate ears with glumes intermediate in size and form between those of the parents.

The grain was also intermediate in size, but purple like that of the *dicoccum* parent.

The F_2 generation showed indistinct 1 : 2 : 1 segregation, with the glumes of the homozygous "long-glumed" plants—24·14 mm. long—somewhat shorter than those of the *polonicum* grandparent: those of the homozygous "short-glumed" segregates being longer than those of the corresponding *dicoccum* grandparent.

c. *T. polonicum* × *T. durum* (Kubanka).—A cross between these wheats was made in 1912 by Backhouse.

The average glume-length of the *polonicum* parent was 29 mm., that of the *durum* parent 12 mm. The F_1 was intermediate, with glume-length 18-19 mm.

In F_2 were long-glumed and intermediate-glumed plants, forming a

group inseparable by eye into two classes, but distinct from the short-glumed segregates. The numbers of each were :

Long and intermediate, 172 ; short, 55 ; or a 3 : 1 ratio.

The Polish wheat used in the cross had faintly pubescent glumes, Kubanka being a glabrous-chaffed wheat. The F_1 was more pubescent than the *polonicum* parent.

In F_2 both smooth and hairy-glumed plants appeared. Among the pure short-glumed plants were three felted to one with smooth glumes : the proportion of pubescent to smooth in the heterozygotes was 85 : 31 (15 strongly felted), while all the pure long-glumed plants had glabrous chaff, the factor for long glume apparently inhibiting pubescence.

Results of a cross between the Polish and Kubanka wheats (*T. durum*) were also investigated by Engledow.

The F_1 was intermediate. The glume-length of the F_2 progeny was determined and compared with the glume-length of the grandparents, the measurements being made of a glume from one of the four median spikelets of each ear.

The mean glume-length of the Polish wheat used in the cross was 30·84 mm., that of the *durum* being 11·7 mm.

In F_2 three glume-length types appeared, the measurements of the glumes yielding a tri-modal frequency curve, the respective modes being 11·5 mm., 16·5 mm., and 25·5 mm. The calculated frequencies of the F_2 segregates were :

23·29 per cent (Extracted Kubanka), 57·76 per cent (Intermediate), 18·94 per cent (Extracted Polish).

To determine more accurately the classification of the F_2, the F_3 generation was raised and measured : the percentages of the three types were :

23·65 (Kubanka), 55·39 (Intermediate), 20·95 (Polish).

The figures suggest a 1 : 2 : 1 ratio, but deviate considerably from it.

A comparison of the measurements of the grandparental forms and the extracted *polonicums* and *durums* in F_2 showed that the true *polonicum* and *durum* types are produced in very small numbers if at all in F_2, the extracted *polonicum* having a mean glume-length from 20 to 25 per cent less than that of the original *polonicum*, and the extracted *durums* somewhat longer glumes than the grandparental Kubanka.

The reduction or " shift " towards the mean glume-length of the two grandparents is most clearly established in the long-glumed or " *polonicum* " segregates of F_2, and the " shifted " form breeds true in F_3, no evidence of additional " shift " or a reappearance of the pure *polonicum* being obtained.

Engledow found that in regard to the length of the grain the F_1

was intermediate between the parents, and segregation into long-, intermediate-, and short-grained plants took place in F_2.

The extracted *polonicums* of F_2 showed the same phenomenon of "shift" in the length of the grain as in the glume-length, but the reduction was less, the grains being only about 12·5 per cent shorter than those of the grandparental *polonicum*.

Engledow found an increase in pubescence in some of the short-glumed F_2 plants similar to that observed by Backhouse.

d. T. polonicum × *T. turgidum*.—These wheats have been crossed by Vilmorin, Tschermak, Biffen, Backhouse, and others, and natural hybrids between them have been recorded by Jordan.

(i.) *T. polonicum* (Bearded) × *T. turgidum* (Pétianelle Blanche, Bearded). —This hybrid was raised in 1881 by Vilmorin. The F_1 plant (1882) had very long, lax, *beardless* ears, with empty glumes intermediate in length between the two parents.

In the F_2 generation (1883) were examples of almost pure *T. polonicum*, together with forms of *T. vulgare* and *T. durum*. Although both original parents had white grain, some of the segregates had red grain.

(ii.) *T. polonicum* ♀ × *T. turgidum* ♂ ("Rivet").—Biffen records the crossing of these wheats, the *polonicum* parent being the common lax-eared form with rachis internodes 6·6 mm. long, pale yellow glumes, almost or entirely glabrous, averaging about 28 mm. long, and white grains: the *turgidum* plant was the dense-eared cone type most commonly cultivated in this country, with rachis internodes about 3·6 mm. long, greyish pubescent glumes about 9 mm. long, and reddish grain.

The F_1 had lax intermediate ears, rachis internodes 5·8 mm. long, with pale greyish or dirty-yellow pubescent glumes, intermediate between those of the parents, measuring 17 mm. in length. The grains of the F_1 plants were red, about 9 mm. long, those of the parents averaging 10·1 mm. (Polish) and 7·2 mm. (Rivet) respectively.

Glume-lengths of 595 plants of the F_2 generation were measured, and the frequency distribution of the several lengths plotted; the curve obtained was sharply divided into three portions, segregation into 149 long-glumed : 304 intermediate : 142 short-glumed plants, suggesting the monohybrid ratio 1 : 2 : 1.

The plants of this generation bore long, intermediate, and short grains, and segregation into white- and red-grained plants also occurred.

Biffen found that the chaff colour of the hybrid and its descendants resembled that of the pale *polonicum* parent. The blue-grey colour of the Rivet ancestor, which in crosses with some other wheats is dominant, was suppressed in this case and did not reappear in any of the plants up to the sixth generation.

A Polish wheat with white and practically glabrous glumes was crossed

by Backhouse with a dark pubescent glumed variety of *T. turgidum*. The average glume-length of the *polonicum* parent was 28-29 mm., that of the *turgidum* 11 mm.

The F_1 was intermediate in length of chaff, varying from 14 to 17 mm. The F_2 generation consisted of a series of plants impossible to separate by eye into long-, intermediate-, and short-glumed classes. The frequency distribution of measurements of the glume-lengths, however, when plotted appeared to give a ratio of 514 long and intermediate : 178 short.

The F_1 generation had felted white or faintly coloured glumes.

In F_2 were pubescent and smooth-glumed segregates, and white, ringed, and deeply coloured ears, the most highly felted and deepest colour being associated with short glumes, the factor for long glume apparently inhibiting colour and pubescence.

e. T. polonicum × *T. vulgare*.—The F_1 of this cross obtained by Tschermak had empty glumes intermediate in length between those of the two parents.

In the F_2 generation *polonicums*, intermediates and *vulgare* forms with glumes somewhat longer than those of the *vulgare* parent were obtained, and in addition a small number (about 6 in 100) of new *durum* forms appeared.

Neither the *polonicum* nor *vulgare* forms of this nor subsequent generations were exactly like the parents of the cross.

The proportion of the several forms were: *vulgares*, 1; *durum*, 3; *intermediates*, 8; *polonicums*, 4; the ratio of the *vulgare* forms to the rest being 1 : 15, suggesting the presence of two pairs of factors.

Some of the *durum* forms were found to be constant, others segregated in the ratio 3 *durum* : 1 *vulgare*.

From the foregoing records of the hybridisation of *T. polonicum* with other wheats it is seen that the F_1 is always intermediate between the two parents in length of ear, form, size, and texture of glume, and form and size of grain.

In the majority of cases segregation into *polonicum*, intermediate and the second grandparental types occurs in the F_2 generation, the ratio being 1 : 2 : 1.

In the natural cross between *T. polonicum* and *T. dicoccum* I found the homozygotes readily distinguishable from the intermediate heterozygotes, but where the second parent is a *durum* or *turgidum* it is practically impossible to classify the F_2 generation into three groups by eye inspection alone, since the ears obviously long-glumed and short-glumed are always connected by a closely graduated series of intermediates.

In the latter cases, however, the curve obtained by plotting the frequency distributions of the measurements of the glumes is tri-modal, corresponding to the three types of segregates.

The mean glume-length of the extracted F_2 *polonicums* is usually 25 per cent less than that of the grandparental *polonicum*, the glumes of the other extracted homozygotes being somewhat longer than those of the corresponding grandparents.

The means of the curves of the glume-lengths of the homozygotes are nearer to the mean of the intermediates than are the means of the original parents. This condensation effect is permanent, the changes in the average glume-length of the extracted homozygotes being hereditary and transmitted without further apparent alteration to the subsequent generation.

It is possible that the observed deviation of the extracted homozygotes from the pure parental forms in the crosses of *polonicum* with other wheats may be due to irregular reduction division in the F_1 generation.

In normal reduction division, a certain number of the gametes produced in the F_1 generation contain only *polonicum* chromosomes, and a certain number only *durum* chromosomes. In irregular reduction division, however, the gametes may never receive chromosomes derived entirely from either parent, and the zygotes from the fusion of such gametes would therefore always exhibit the characters of both parents in greater or lesser degree.

5. HYBRIDS OF *T. turgidum* WITH OTHER WHEATS.

a. T. turgidum × *T. monococcum* (see p. 391).

b. T. turgidum × *T. polonicum* (see p. 397).

c. T. turgidum × *T. Spelta.*

T. turgidum (Rivet), var. *dinurum* × *T. Spelta*, var. *Duhamelianum* (Red Tyrol Winter Spelt. Beardless Red Chaff).—This hybrid obtained by H. Stoll gave an extraordinary number of forms in F_2, among which were several " Squareheads " with and without awns and a beardless *compactum*.

The glumes were white, red, or bluish and pubescent, like the Rivet parent. One of the beardless *Spelta* forms with red chaff and large, plump spikelets and grain was selected and remained constant after 1904, when it was placed on the market as Stoll's Early Giant Spelt.

The F_1 in the *Spelta-vulgare* and *Spelta-turgidum* crosses is intermediate in ear characters, with a more or less brittle rachis and tightly fitting glumes, like the *Spelta* parent. So far as can be gathered from the published accounts, segregation occurs in the F_2 generation in the expected Mendelian ratios, and no forms appear of races other than those of the two grandparents.

d. T. turgidum × *T. vulgare.*

i. *T. turgidum* (Rivet), var. *iodurum* ♀ × *T. vulgare* (Red Schlanstedt) ♂.—Rimpau crossed these wheats in 1875. The F_1 resembled the male parent. In the F_2 were many intermediate forms between completely bearded and beardless.

The characteristic four-sided ear of *turgidum* was absent.

The glumes were chiefly red with some of bluish tint suggestive of the *turgidum* grandparent; a few forms with white chaff appeared.

He also crossed Rivet with a "Squarehead" white-glumed wheat, obtaining a beardless F_1 with pubescent chaff of several shades of bluish black.

The F_2 exhibited a large variety of forms, some of which were quite sterile.

ii. *T. vulgare*, var. *albidum* ♀ (Chidham d'automne) × *T. turgidum*, var. *dinurum* (Roux velu de Beauce).

iii. *T. vulgare*, var. *pyrothrix* ♀ (Blé seigle) × *T. turgidum* ♂ (Poulard Blé Buisson).—Vilmorin made these crosses in 1879. The F_1 in both cases was "beardless" like the *vulgare* parents, with short awns at the tip of the ear, the glumes slightly downy and somewhat inflated like those of *T. turgidum*.

In the F_2 generation appeared an extraordinary series of *vulgare* and *turgidum* forms—tall, dwarf, bearded and beardless, some with lax ears, others with very dense ears. In addition, from the hybrid (ii.) was obtained a plant with the pith, glumes, and long, pointed, flinty grain of *T. durum*, while among the progeny of hybrid (iii.) were forms of *T. Spelta*, some of them with branched ears.

6. Hybrids of *T. vulgare* with other Wheats.

a. *T. vulgare* × *T. monococcum* (see p. 392).

b. *T. vulgare* × *T. durum* (see p. 394).

c. *T. vulgare* × *T. polonicum* (see p. 398).

d. *T. vulgare* × *T. turgidum* (see p. 399).

e. *T. vulgare* × *T. compactum* (see p. 403).

f. *T. vulgare* × *T. Spelta*.

The above crosses give fertile reciprocal hybrids, but according to Stoll success is most easily secured when *T. vulgare* is the mother.

i. *T. Spelta*, var. *album* ♀ (White Beardless Spelt) × *T. vulgare*, var. *ferrugineum* ♂ (Bearded Red Chaff).—In 1876 Rimpau made this cross, the F_1 bearing almost beardless Spelt-like ears with slightly reddish chaff.

The F_2 in 1878 gave all the eight possible combination forms of the three pairs of allelomorphic characters (bearded and beardless, red chaff and white chaff, tightly fitting and loose chaff) except white beardless *T. vulgare*.

In the F_3 all eight forms were found, together with a white, dense-eared *compactum* form.

ii. *T. Spelta*, var. *Duhamelianum* (Rose imberbe), Beardless, Red Chaff × *T. vulgare*, var. *anglicum* (Blanc à duvet), Bearded, White Velvet Chaff.—Vilmorin records the crossing of these in 1878.

The F_1 was intermediate, the ears reddish, pubescent, with somewhat

fragile axis and tightly fitting glumes, though less so than the Spelt parent.

In F_2 many forms were found, some Spelt-like with red and white chaff, others like ordinary wheat with white and reddish chaff, both glabrous and pubescent : none were completely like either of the parents first crossed.

iii. *T. vulgare*, var. *lutescens* (Main's Stand-up), Beardless, White Chaff × *T. Spelta*, var. *Duhamelianum* (Beardless Red-chaffed Winter Spelt).—Two constant Spelt wheats were obtained by H. Stoll from this hybrid, one with white and the other with red chaff. The red-chaffed form, placed on the market in 1902, has beardless ears, wide spikelets, with plump, flinty grain and strong straw, and is highly resistant to frost and rust.

The following successful hybrids of *T. Spelta* and *T. vulgare* were also made by H. Stoll :

Bordier × Red Tyrol winter Spelt.

Heine's Squarehead × Red Tyrol winter Spelt and its reciprocal.

iv. *T. Spelta*, var. *Duhamelianum* (Beardless, Red Chaff) × *T. vulgare* (Squarehead, Beardless, White Chaff).—The F_1 of this cross made by Miczynski had lax, beardless ears and wide spikelets. Four different segregates were found in F_2, viz. : 4 *Spelta* forms, 8 like F_1 ; 3 Squareheads ; 1 *compactum* form or 1 *Spelta* ; 3 non-*Spelta* forms.

7. HYBRIDS OF *T. compactum* WITH OTHER WHEATS.

Triticum compactum × *T. vulgare*.—Many hybrids have been obtained between these races of wheats, the chief results being described below :

i. *T. compactum*, var. *Humboldtii* (Little Club) × *T. vulgare*.

ii. *T. compactum*, var. *rufulum* (Red Chaff Club) × *T. vulgare*.

In 1899 Spillman crossed " Little Club " and " Red Chaff," two varieties of *T. compactum*, with several sorts of long-eared varieties of *T. vulgare*.

The F_1 in the majority of cases was intermediate in length and density of ear between the parents. In F_2 there appeared long-eared, short-eared, and intermediate plants : in some instances the numbers of each approximated to the ratio 1 long-eared : 2 intermediate : 1 short-eared, while in others every gradation was found between the grandparents, and in addition, some examples with both longer and shorter ears than these.

Where " Farquhar "—a long-eared, beardless, brown velvet-chaffed *T. vulgare*—was crossed with the beardless little Club, the F_2 in some cases consisted chiefly of long-eared individuals with few or no intermediates or *compactums*.

iii. *T. vulgare* ♀ (Red King, Beardless) × *T. compactum* ♂ (Rood Koren, Bearded).—In 1902 Wilson crossed Red King, a long-eared,

somewhat dense, beardless form of *T. vulgare* (said to be a hybrid), with Rood Koren, a bearded *T. compactum* from South Africa.

The F_1 plants had squarish compact ears of intermediate length with a few awns about 1 inch long at the tip, the *compactum* parent being fully bearded with awns $2\frac{1}{2}$-$3\frac{1}{2}$ inches long.

In F_2 four forms appeared, viz., short-eared, long-eared, awnless, and awned, the numbers of each being :

664 awnless, 207 awned ; 643 short-eared, 229 long-eared, the ratios approximating to the monohybrid 3 : 1 type.

Little variation in length and density of ear was observable among the long-eared segregates, but the short-eared forms were less uniform, and a few plants had exceptionally compact ears.

The long-eared, beardless plants of this F_2 generation gave in F_3 almost entirely long-eared, beardless progeny, the bearded F_2 plants giving a similar preponderance of awned, long-eared descendants.

The short-eared, bearded plants of F_2 gave mostly bearded progeny in F_3, the length of ear showing considerable variation : the corresponding short-eared, beardless forms proved to be similar in constitution to the F_1 hybrid, and, like it, gave four types in F_3.

iv. *T. compactum*, var. *Humboldtii* ♀ × *T. vulgare* ♂ (Epp Wheat).—Rümker crossed these wheats, the F_1 being a typical "Squarehead" intermediate in ear-density between the two parents. In F_2 segregation was of the monohybrid 1 : 2 : 1 type, this generation consisting of 21 Epp : 37 Squarehead : 20 *compactum*.

A Squarehead of F_2 split similarly in F_3, giving 18 Epp : 49 Squareheads : 21 *compactum*.

v. *T. vulgare* ♀ (White Frankenstein) × *T. compactum* ♂ (White Velvet Igel).—This cross obtained by Rimpau gave more complex results. The F_1 generation consisted of four plants, one, a typical beardless Squarehead, the others produced both beardless long and lax ears and Squarehead-like ears on the same plants.

In F_2 were obtained five forms, viz. :

a. 21 beardless Squareheads.
b. 12 beardless, dense-eared, not typical Squareheads.
c. 5 bearded Squareheads.
d. 8 lax-eared, beardless plants of the Frankenstein type.
e. 1 lax-eared, bearded plant.

38 dense : 9 lax (4 : 1).
41 beardless : 6 bearded (7 : 1).

Two of the beardless Squarehead plants (*a*) gave all bearded descendants in F_3.

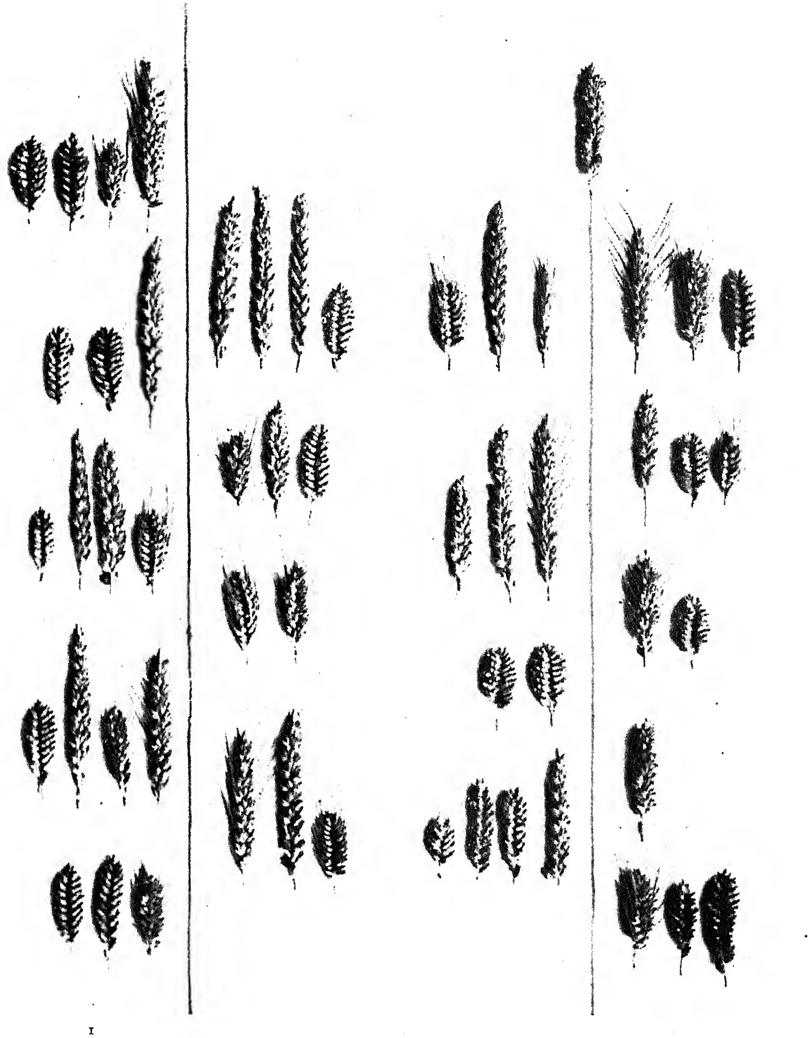


Fig. 226.—Segregates raised from the Individual Grains of each Spikelet of an Ear of a Natural Hybrid (*T. vulgare* × *T. compactum*), arranged in order from the base (1) to the apex (2) of the ear.

From one of the bearded Squareheads (*c*) were obtained in F_3 11 bearded glabrous and 35 beardless glabrous Squareheads

= Bearded, 1 : Beardless, 3.

Another gave 15 bearded Squareheads, 58 beardless Squareheads, and 2 lax-eared, beardless plants.

Bearded, 1 : Beardless, 4.

vi. *T. vulgare* ♀ (Velvet Kolben, Beardless) × *T. compactum* ♂ (Velvet Igel, Bearded).—The F_1 of this cross obtained by Rümker was of intermediate ear-density with white velvet chaff and beardless ears.

In F_2 appeared plants with bearded and beardless ears, some long and lax, others of intermediate length and denser, though none were of the "Squarehead" type. Although both grandparents were velvet-chaffed, glabrous-glumed forms appeared in this generation.

Ratios :—Velvet-chaffed, 3 : Glabrous, 1. Bearded, 5 : Beardless, 101.

Biffen crossed a long-eared *vulgare* (Devon) with *T. compactum* (Hedgehog) and found the F_1 intermediate. Strampelli also obtained an intermediate F_1 hybrid from *T. compactum* (Hérisson) × a lax, long-eared *T. vulgare* (Rieti), the F_2 giving *compactums*, intermediates, and long-eared forms in the ratio 1 : 2 : 1.

vii. *T. compactum* (Swedish Binkel) × *T. vulgare*.—The crossing of *T. compactum* with *T. vulgare* was extensively studied by Nilsson-Ehle, who crossed Swedish Binkel, an old beardless form of *T. compactum*, with three long, lax-eared forms of *T. vulgare*.

The F_1 plants had ears somewhat longer and laxer than those of the *compactum* parent, resembling an ordinary "Squarehead." In F_2 appeared long, lax-eared, homozygous, recessive forms sharply separated from a group of "Squarehead" heterozygotes and homozygous *compactums*, the two latter not always clearly differentiated from each other, but whose genetic constitution was revealed in the F_3 generation.

The ratios of the F_2 were of the ordinary monohybrid type, viz. :

1 *compactum* : 2 Squareheads : 1 Long-eared.

The same variety of *T. compactum* was also crossed with "Pudel" and "Bore" wheats—comparatively dense-eared "Squarehead" forms of *T. vulgare*.

The F_1 of these crosses was dense-eared, closely resembling the *compactum* parent. Segregation in F_2 was complex, no sharp distinction being visible between the *compactums* and non-*compactums*.

In one example of the cross Binkel × Pudel (Squarehead), the F_2 consisted of 61 *compactums*, 5 of them denser than the "Binkel" grandparent; 5 *compactum*-like plants and 28 non-*compactums*, chiefly very lax-eared, only two being as dense as the Pudel grandparent.

The progeny of these in F_3 is indicated below :

F_2 generation.	F_3 generation.
5 very dense *compactums* . .	5 constant *compactums*.
56 *compactums*	18 constant *compactums*. 38 segregating into *compactums* and non-*compactums*.
5 *compactum*-like . . .	5 segregating into *compactums* and non-*compactums*.
28 not *compactums* . . .	Only non-*compactum* progeny, but of variable ear length and density.

The F_3 results show that the F_2 generation consisted of 23 homozygous *compactums*, 43 heterozygotes, and 28 homozygous non-*compactums*, suggestive of the simple monohybrid 1 : 2 : 1 ratio.

Similar gradation of density of ear between the compact and laxer-eared segregates occurred in the F_2 generation of the cross " Binkel " × " Bore " wheat, but the nature of the plants of the F_2 generation was cleared up in the F_3 progeny :

F_2 generation.	F_3 generation.
46 *compactums*	25 constant *compactums*. 21 splitting into *compactums* and non-*compactums*.
31 less dense *compactums* . .	Splitting into *compactums* and non-*compactums*.
11 Binkel " Squareheads " . .	Do.
1 " Squarehead "	Do.
37 plants with lax ears . . .	Descendants all non-*compactums*, but exhibiting considerable variation in ear-density.

The results of the F_3 generation show that the F_2 consisted of 25 homozygous *compactums*, 64 heterozygotes, and 37 homozygous non-*compactums*, approximating as in the previous cross to the 1 : 2 : 1 ratio.

The results obtained by Nilsson-Ehle led him to believe that in the long lax-eared " Landwheats " two independent factors L_1 and L_2 are present, each of which, by itself, increases the length of the internodes of the ear ; when both factors are present their effects are cumulative.

The dense ear of *T. compactum* he considers due to a factor C which shortens the rachis-internodes and is epistatic to L_1 and L_2.

On this hypothesis plants of the genetic constitution CL_1L_2, CL_1l_2, Cl_1L_2, as well as those containing the C factor alone (Cl_1l_2), would have short *compactum* ears, though not all of equal ear-density, since the L factors are not completely masked by the presence of C.

From analysis of his results he concluded that the Swedish Binkel is a

CL_1L_2 *compactum*, and that the " Squareheads," Bore and Pudel, are of the constitution cl_1l_2, neither the factors C nor L_1 or L_2 being present in these wheats.

In the crossing of *T. compactum* CL_1L_2 with *T. vulgare*, where the *vulgare* parent is of the long lax-eared form cL_1L_2, the *compactum* is generally dominant but not completely so, the F_1 often resembling the " Squarehead " wheats. In F_2 segregation occurs into long-eared plants, intermediate and *compactums* in the ratio 1 : 2 : 1, but exact measurements of the internodal lengths of the rachis are often necessary to establish the ratios. The heterozygotes, though found to be somewhat less dense than the homozygous *compactums*, form with them a group sharply differentiated from the long lax-eared plants.

New combinations of the factors in the cross between a *compactum* of the constitution Cl_1l_2 and a lax-eared " Landwheat " cL_1L_2 would result in the production of " Squareheads " (cl_1l_2) in F_2 : these were found by Nilsson-Ehle, though their number was not so large as the expected 1 in 3. The " Squareheads " of Rimpau's hybrids may have arisen in this way.

In crosses between *T. compactum* and the denser-eared *vulgares* or Squareheads, the F_1 very closely resembles the *compactum* parent. Segregation in F_2 is complex and apparently impure, long lax-eared forms longer than the Squareheads, and *compactums* denser than the Binkel appearing with forms resembling the two grandparental wheats.

The cross between the Binkel *compactum* and Bore " Squarehead " may be represented thus :

$$CL_1L_2 \text{ (Binkel)} \times cl_1l_2 \text{ (Squarehead).}$$

From the hybrid F_1 four forms would appear in F_2, viz. : Cl_1l_2 (very dense *compactum*), CL_1L_2 (Binkel), cl_1l_2 (Squarehead), cL_1L_2 (long lax-eared forms) ; the first and last being new hereditary types respectively denser and laxer than the *compactum* and Squarehead grandparents.

As previously noted, all these were obtained by Nilsson-Ehle, and the appearance of the very dense and very lax ears in some of Spillman's *compactum* × *vulgare* hybrids may be explained in a similar manner.

The C factor acts more strongly in shortening the ear internodes of the long-eared wheats than those of the Squarehead form, and the *compactums* CL_1L_2, CL_1l_2, Cl_1L_2, Cl_1l_2 form a graduated group less homogeneous than the non-*compactums* (Squareheads l_1l_2 and " Landwheats " L_1L_2) of the same cross.

8. Hybrids of *T. sphaerococcum* with other Wheats.—*T. sphaerococcum* × *T. dicoccum* (see p. 392).

9. Hybrids of *T. Spelta* with other Wheats.—*T. Spelta* × *T. vulgare* (see p. 400).

VI. Hybrids of Varieties and Forms of the same Race of Wheat

By far the greatest number of wheat hybrids have been produced by the crossing of varieties and forms belonging to the same race, and the hybridisation of the *vulgare* forms is assiduously carried on by many workers in almost all the large wheat-growing countries.

The inheritance of the several differentiating characters is generally in agreement with the conclusions summarised in pages 363-377.

CHAPTER XXVI

THE IMPROVEMENT AND BREEDING OF WHEAT

THE amelioration or improvement of plants consists in securing and propagating individuals possessing in greater degree than the unimproved form those characters which render them useful or attractive to man.

Such improvement is dependent upon three factors, namely: (1) variation, (2) heredity, and (3) artificial selection.

If all plants were exactly alike no improvement would be possible; moreover, in the case of plants, such as wheat, which are propagated from seeds, unless the desirable variation from the ordinary type is hereditary it is useless.

It is important to emphasise the fact that the creation of plant characters is beyond human power, and the causes which lead to the production of hereditary variations are quite unknown.

Given, however, the improved hereditary variant, all that is necessary is to select and isolate it from its neighbours and grow it. Such selection is, in fact, the only means of improving plants. Selection, of course, does nothing more than select, and in itself produces or creates nothing, although it is frequently tacitly assumed to be causally responsible for the modifications which are secured.

The new individuals which are selected may arise spontaneously among ordinary crops, or they may appear among the progeny of artificial hybrids.

It should, however, be clearly understood that in the improvement of plants hybridisation does nothing more than manufacture material upon which selection can be exercised. Without selection, it leads to the production of a multiplicity of forms, and consequent confusion.

By crossing, individuals are obtained which differ from the parental forms, but the differences are due only to a recombination of already existing characters and not to the creation of any new character.

In the improvement of wheat three methods of selection are practised, namely: (1) mass selection, (2) selection of spontaneously occurring individuals, and (3) the selection of plants with desirable characters from the descendants of artificial hybrids.

Mass Selection.—The selection of a number of the best ears from an ordinary crop of wheat, and the grading of the grain by sieves and other machines in order to obtain the largest for use as seed, has been practised by the most advanced agriculturists in all ages. Virgil (*Georgics*, i. 197) says :

> "I've seen the largest seed, tho' viewed with care,
> Degenerate, unless the industrious hand
> Did yearly cull the largest."

Columella (*De re rustica*, ii. 10) also refers to the necessity for sifting out the largest grains for use as seed, and mentions that Celsus advises, where the crop is small, to pick out all the best ears and store them for seed; Varro (*De re rustica*, i. 52) similarly advises the selection of the best ears for seed.

The process of mass selection, as generally practised, consists in choosing from the standing crop 100, 1000, or some other arbitrary number of ears possessing characters which the plant-breeder considers it desirable to fix or increase. The choice may be based upon the exceptional length or density of the ear, the number of grains in the spikelets, the height of the straw, or other characters. The grains from these selected ears are sown, and from their progeny a further selection is made, and the process repeated annually as long as it is deemed desirable.

When carried out by skilled observers acquainted with the morphological differences of wheat plants, mass selection rapidly leads to the establishment of a uniform type of plant from a variable crop, and apparently new or improved forms have been frequently obtained by this means in various countries. When the characters upon which the selection is based are correlated with prolificacy of the plants, it results in the production of a crop whose yielding capacity gradually increases from year to year as the selection is continued.

Where improvement occurs, it is the custom to assume that the crop is, in the first instance, a mixture of a number of distinct and independent forms and the selection does nothing more than isolate one of these from the rest, just as a white-chaffed form would be established by selecting all the ears with white chaff from a field mixture of white- and red-chaffed wheats.

Whatever the explanation, the fact remains that mass selection has led to an improvement in the yield and uniformity of the crop when applied to fields of wheat as ordinarily cultivated on the farm, and it is a method which should not be abandoned nor despised.

Apart from the possibility of obtaining new forms by its means, the process is invaluable in maintaining the purity of those wheats which have descended from single ears.

Individual Selection.—The selection of single ears or plants and their

subsequent propagation has produced the majority of the world's most famous wheats.

The practice was initiated by Le Couteur and Shirreff in the early years of the nineteenth century, and was subsequently adopted in this country by Hallett, by Vilmorin in France, Nilsson at Svalöf in Sweden, and Hays in the United States.

All the widely grown English wheats of last century originated in this manner. Chidham wheat was derived from a plant found in a hedge in Sussex; Fenton came from a three-strawed plant discovered in a quarry in Scotland; Hunter's White was the progeny of a plant taken from the roadside, and Browick and Squarehead wheats were descended from single "rogue" plants growing among crops of another kind.

Similarly, the American Fultz originated from three beardless ears observed in a field of Lancaster wheat, and the renowned Canadian Fife was derived from a single plant grown from a mixed sample of imported European wheat.

The true ancestry of these selected plants can only be surmised. In some instances it is probable that they are stray plants of kinds already cultivated elsewhere. Others are doubtless ordinary Mendelian segregates from recently produced natural hybrids. The majority, however, appear to be hereditary sports or mutations arising out of plants whose remote ancestors were hybrids. A few may be variants unconnected with hybridisation and due to causes which are at present unknown.

After the initial selection of a special ear or plant, the time required to obtain a sufficient quantity of grain to sow in the field is comparatively short, enough for the ordinary seeding of 15 to 20 acres being easily secured at the third harvest, without adopting any very special methods for increasing the crop.

The following is a typical example of the rapidity of multiplication of a new form of wheat from a single ear, the results being obtained by Mr. Jonas of Liverpool in 1838–41.

Fifty grains taken from a selected ear were sown (dibbled) in 1838. Only thirty grew, but the produce from these was $14\frac{3}{4}$ oz. From this quantity he obtained $1\frac{1}{4}$ bushels in 1839, which returned 45 bushels in 1840. From the latter amount he harvested 537 bushels in 1841, four years after the selection of the single ear.

A good ear usually yields from 4·5 to 5 grs. of grain, which when sown on good land in rows 9 inches apart each way will produce rarely less than 450 grs.—about 1 lb. at the first harvest. This amount sown thinly yields about 1 bushel of grain or 60 lbs. at the second harvest, which when sown on an acre of good land in clean condition generally produces 35 to 40 bushels (third harvest).

Shirreff laid special emphasis upon the initial selection, and con-

sidered that after this was made, all that was needed was to grow and multiply the selected plant.

Hallett, on the other hand, did not specially seek for exceptional plants, but endeavoured to improve those already in cultivation, by means of "pedigree" culture, believing that the good qualities of the plant could be increased by this process, which consists in repeated selection of the best plants in successive generations, and propagation from these only.

Beginning with a single plant or ear, he made an annual choice of the most prolific individual, being convinced that as good effects of continued selection would be secured among the crops as among the animals of the farm.

The grains from the chosen ears were sown singly in rows 1 foot apart, the grains being deposited in holes 1 foot asunder in the row. At harvest the individual plants were examined, and the best in respect of their grain production, length of ear, or tillering power was selected for further propagation. From this *élite* plant the best ear was isolated and its grain sown, the plants produced being subjected to the same careful scrutiny at the following harvest.

By this process he considered that the good qualities of the original selected plant were not only maintained but increased from year to year.

The following are the results which he records after four years' selection of Red Nursery wheat :

	Length.	No. of Grains.	No. of Ears on the Best Plants.
	inches.		
1857. Original ear	$4\frac{3}{8}$	47	. .
1858. Finest ear	$6\frac{1}{4}$	78	10
1859. Finest ear	$7\frac{3}{4}$	91	22
1860. Ears imperfect owing to wet season	. .	. .	39
1861. Finest ear	$8\frac{3}{4}$	123	52

"Thus," he states, "by means of repeated selection *alone* the length of the ears has been doubled, their *contents* nearly trebled, and the tillering power of the seed increased five-fold."

These figures only indicate an increase in the length and number of grains of the finest ears in successive generations, but give no evidence of any improvement in the averages of these characters. They may indeed be taken to indicate nothing more than wider fluctuating variability in carefully cultivated progeny of selected ears.

Nevertheless, Hallett, who was an advocate of thin seeding, secured some extraordinary crops of grain from his pedigree seed, in one instance

obtaining $1\frac{3}{4}$ bushels on 698 square feet (108 bushels per acre) of unmanured land, from pedigree Nursery Red wheat seed sown singly in rows 9 inches apart each way. Further, there was in his lifetime a widespread belief in the superior quality of his pedigree seed.

In recent times there has been much scepticism regarding the possibility of obtaining modifications of particular characters by repeated or "pedigree" selection applied to the progeny of a single self-fertilised plant such as wheat.

The doubt has arisen in consequence of the experimental results of Johannsen, who failed to secure any significant alteration in the average size of Dwarf beans (*Phaseolus vulgaris*) by selecting either the largest or the smallest seeds in successive generations of self-fertilised descendants which originally sprang from a single individual bean.

To the progeny of a single homozygous organism propagated by self-fertilisation, Johannsen applied the term *pure line*, and his evidence and that of others has led to the conclusion that selection within such a line has no effect.

All that can be legitimately concluded, however, from these experiments is that variations of the fluctuating type (p. 346) are not inherited; but to assume that so-called pure lines are incapable of heritable variation is unwarranted, for hereditary sports or mutations, though somewhat rare, do occur among the descendants of wheats raised from single ears.

Commencing with a single ear of average length, repeated "pedigree" selection will lead with certainty to the production of a line with an increased average length if hereditary sports with longer ears arise during the time selection is continued.

Since mutations are erratic, often small, and comparatively rare, the time taken to obtain improvements by selecting within lines descended from single individuals will necessarily be subject to much variation. Nevertheless, in spite of the irregularity of the results, the method should not be discontinued or cast aside as useless.

Selection of Hybrids and their Descendants.—The observed variability of hybrids and their offspring soon led to the employment of hybridisation as a means of producing desirable varieties from which improved forms could be obtained by selection. In the formula of the plant-breeders of last century, crossing of stable varieties was practised in order to "break the types" or induce them to sport, after which the fixation of desired forms by repeated selection was undertaken.

All the early wheat hybrids were produced with this object. Among the most prominent and successful breeders who adopted this method of wheat improvement were Shirreff in this country, Vilmorin in France, Rimpau in Germany, Pringle and Blount in the United States, and Saunders in Canada.

At first the crossing was of a simple character between two kinds of wheat, the grains of the hybrid plant being sown and selection made from the progeny. Later, Farrer in Australia, Jones in America, and the Garton Brothers in England resorted to multiple crossing, the first hybrid being immediately crossed with a third form, and the plant produced crossed with another wheat, successive hybridisations with different forms being continued for several seasons.

The following is an example of such multiple crossing, from which the Australian wheat Bunyip was derived :

Blount's Lambrigg × Hornblende

Improved Fife × Purple straw — An unnamed hybrid × King's Jubilee

Rymer ♀ — Maffra ♂

Bunyip.

In the majority of cases there was little or no system in the choice of parents of these simple multiple hybrids, the chief object being to obtain immediate variation, and wheats chosen at random frequently gave satisfactory results from this point of view.

Farrer and others, however, first obtained a clear conception of the desired improvements, and selected the plants to be crossed only after a careful study of their morphological and physiological characters, in some instances subjecting the parents to pedigree culture before hybridisation.

Although the methods of the early hybridists were of a somewhat haphazard nature, they led to the production of many valuable wheats, among which may be mentioned Vilmorin's Bon Fermier and Dattel, Pringle's Defiance, Jones's Winter Fife and Early Red Clawson, Saunders's Marquis and Preston, and the Australian wheats Federation and Comeback, produced by Farrer.

Before 1900 the result of hybridisation was a matter of chance and its nature could not be foreseen, since no reliable generalisations were available regarding the transmission of the characters of the parents to their offspring in the case of sexually produced plants.

About the date mentioned the rediscovery of the Mendelian laws of inheritance removed some of the uncertainty of hybridisation, and the plant-breeder is now able to predict with a high degree of assurance the character of the offspring derived from the crossing of parents possessing certain morphological and physiological features.

Many of the characters of the wheat plant, such as the presence or absence of awns, the colour of the chaff and grain, the hairiness and smoothness of the chaff, and the solid or hollow condition of the straw are dependent upon single Mendelian factors, which are transmitted from parent to offspring independently of each other, and the plant-breeder is

able to treat these as separate hereditary units, which can be added or removed at will.

Moreover, he is able to combine in one plant many of the characters possessed by two or more different varieties, and from a knowledge of the established Mendelian ratios the selection of desirable forms which will breed true is simplified and rendered more certain. For example, from a red-chaffed, red-grained wheat and a white-chaffed, white-grained variety it is easy to obtain both white-chaffed red-grained and red-chaffed white-grained individuals, and plants constant to these new combinations of characters can be selected with certainty from the second generation of the hybrid's descendants.

By crossing any of the forms just mentioned with plants having glabrous or pubescent glumes, these latter characters can be introduced into the progeny of the hybrids, and, similarly, the bearded or beardless characters can be added to plants in which they are absent.

In the chapter on hybridisation (Chap. XXV.) the mode of inheritance of many of the different characters of the wheat plant is indicated so far as it has been determined, and the knowledge can be utilised for the production and breeding of plants in which are present any combination of the separate characters there discussed.

Unfortunately, colour of chaff and grain, presence and absence of awns, and most of the characters whose inheritance has been clearly established are of no economic importance.

The character which above all others it is desirable to control and utilise is the grain-yielding capacity of the plant, but this, like almost all quantitative characters, either does not Mendelise or is beyond present Mendelian analysis, and its manifestation is so greatly influenced by so many external conditions that its inheritance is obscured.

Other characters which it is desirable to improve on account of their bearing upon yield are length of growing-period, resistance to drought, frost, and lodging, and immunity to diseases, all of which are of a highly complex nature, and their inheritance in terms of Mendelian factors still uncertain.

Whatever methods are adopted for the improvement of wheats, it is essential that a clear conception should be obtained of the ideal towards which the plant-breeders' efforts are directed. This is especially necessary since the aims of the breeder vary in different countries ; the wheat which best suits the English farmer is useless in Central Europe, India, or Australia, and *vice versa*.

Moreover, real progress can only be made by those who are thoroughly familiar with the morphological details and variability of the wheat plant, and the raising of improved kinds adapted to the requirements of the grower to be successful must be carried on in the country in which the

varieties are to be cultivated and under the conditions which allow of the full development of the desired characters.

Where high grain production is desired, selection of forms possessing a naturally long growing period is essential. Nevertheless, the climatic conditions of the country in which the improved wheats are to be grown must be considered, for, although the long-lived English wheats give excellent yields in this country, they are unable to complete their life-history in India, and are useless there, being easily surpassed in grain production by the rapid-growing short-lived endemic forms.

On the other hand, Indian varieties are valueless here on account of their short growing period and consequent low yield.

The breeding of drought-resistant forms is not likely to be successful when prosecuted in a humid climate, nor can rust-resistant varieties be secured or isolated in the absence of rust fungi.

In all wheat-growing regions the primary object of the cultivator is to obtain the highest financial return from the land, and in the majority of cases this result is only secured by the growth of wheats which give the greatest yield of grain. High yield is, in fact, the ultimate aim of the plant-breeder when he directs his attention towards the production of varieties which are resistant to drought, frost, and diseases.

So-called " strength " of grain is important, but wheats of the highest quality in this respect invariably give small yields, and the consumer or his agents rarely pay enough for the superior quality to cover the loss due to diminished yield. It usually pays the producer to grow wheat of inferior milling quality, and this has been specifically recognised and adopted as a sound policy by the most successful wheat growers during the last two hundred years in this country.

Throughout Western Europe wheats of the highest quality have been abandoned as unprofitable, and in other regions where the cost of cultivation is increasing, wheats of high quality and low yield are being replaced by better yielding sorts of inferior quality.

The growth of wheat of inferior milling quality is sometimes condemned, but as Cobb has well said : " Farmers do not grow wheat for philanthropic reasons ; they grow it to make money, and it will be a long time before they grow it for any other reason." . . . " Give the grower a new wheat that will bring him more money for his outlay, and he will grow it whether the consumers starve on it or grow fat."

CHAPTER XXVII

YIELD

THE world's annual harvest of wheat at the present time reaches the enormous total of more than 3500 millions of bushels, and efforts to increase it are continually being made.

Its cultivation is being extended into new country, and in districts where its growth is already established there is unceasing endeavour to increase the yield by improvement in the methods of cultivation, the application of fertilisers, the selection of new varieties better adapted to the climatic and soil conditions, and the use of superior seed.

In the table below are given approximate figures for the total amount raised annually in the various wheat-growing countries, together with the average yield per acre.

	1908–1913.			1908–1913.	
	Average Annual Yield.	Average Yield per Acre.		Average Annual Yield.	Average Yield per Acre.
	millions of bushels.	bushels.		millions of bushels.	bushels.
Denmark . .	4½	?	Chili . . .	21	14
Belgium . .	15	37	Spain . . .	130	13
Holland . .	5	35	Australia . .	90	12
Switzerland .	3½	32	India . . .	351	12
United Kingdom	60	32	Asiatic Russia .	120	12
Germany . .	153	32	European Russia	666	11
Sweden . .	8	31	Argentina . .	147	11
New Zealand .	7	(31)	Greece . .	(8)	11
France . .	317	20	Mexico . .	(5)	10
Austria . .	60	20	Uruguay . .	7	10
Japan . . .	24	20	Persia . .	(16)	10
Canada . .	204	19	Turkey in Europe	(22)	11
Hungary . .	169	19	Turkey in Asia .	(33)	10
Roumania . .	88	19	Algeria . .	35	10
Italy . . .	183	16	Portugal . .	8	9
Egypt . . .	34	16	Union of S. Africa	6	9
Serbia . . .	14	15	Tunis . . .	6	6
Bulgaria . .	46	15			
United States .	685	14	The world's average .		. 13

At the head of the list in point of total yield stand the United States

and European Russia, each with an annual harvest of over 600 millions of bushels. Occupying the third and fourth places, with yields of over 300 millions, are France and India, followed by Canada with some 200 millions. Other countries whose harvests yield from 150 to 180 millions of bushels are Italy, Hungary, Germany, and Argentina.

While all countries which grow wheat use it for bread-making, some of them produce more than they need and export it to others whose crop is insufficient for their requirements.

From 500 to 600 millions of bushels are needed by the importing countries, about four-fifths being supplied by the United States, Canada, Russia, and Argentina. Of all countries the United Kingdom imports by far the greatest amount, some 200 millions being required annually. Holland and Belgium absorb about 60 millions each, while Italy takes between 40 to 50 million bushels.

While the total yield of grain which a country produces is of national interest, the yield per acre is of primary importance to the farmer, and all his efforts are directed towards improving it.

In a class by themselves may be placed the countries in which the average yield is over 30 bushels per acre, and with the exception of New Zealand all are found in Western Europe. The conditions governing these high yields are the rainfall during the growing period and the climatic conditions which allow of the cultivation of winter wheats with a long growing period, together with the intensive cultivation and manuring of the soil which is practised in these countries.

In contrast with these countries are the large numbers in which the average yield is below 20 bushels per acre. On account of the severity of the winters, the low rainfall, or the very brief growing season, only spring wheats of short growing period can be grown, and the difficulties connected with the cost of better cultivation and manuring of the land militate against higher yields.

The average yields of wheat in this country have risen gradually from the earliest times down to the present day. Rogers states that 8 bushels or less was the average yield during the first half of the fourteenth century, and records of 3 to 6 bushels are not infrequent at that period, the amount sown being about 2 bushels per acre.

In the thirteenth century Walter of Henley gives 10 bushels per acre as a fair return, and incidentally remarks that if the yield is only three times the amount of the seed sown (*i.e.* 6 bushels per acre) a farmer will gain nothing unless the price of grain is abnormally high.

In the work on "Hosebonderie," written in the early part of the fourteenth century, it is said that "wheat ought by right to yield to the fifth grain," *i.e.* 10 bushels per acre.

From this period up to the middle of the sixteenth century, yields of

8 or 10 bushels were considered normal. There was no rotation of crops, and little or no manure was applied to the soil, which was worn out and poorly cultivated.

When the soil became exhausted the land was fallowed and allowed to lie idle for a whole year, during which period it was ploughed several times. After this treatment returns of 8 to 10 times the amount of seed sown (*i.e.* 16-20 bushels) were not infrequently obtained. The ground was thereafter cropped annually, the yields diminishing until no more than a three- or four-fold return was secured, when the fallowing process was again repeated.

With the introduction of stock-raising in the early part of the seventeenth century a greater amount of manure became available, and the land was better cultivated, average yields rising to 12 or 14 bushels per acre.

Improvement continued slowly during the seventeenth century, and at its close average yields of 18 to 20 bushels were estimated by contemporary writers.

In the eighteenth century further progress was made, and the average of 23 or 24 bushels per acre is given for the wheat crop by the authors of the county agricultural surveys carried out for the whole of Great Britain during the last few years of the eighteenth and the first ten years of the nineteenth centuries.

In the middle of the nineteenth century Pusey, Caird, and others estimated the yield at 26 or 27 bushels; at the end it had risen to 30 bushels.

The average yield per acre during the first twenty years of the twentieth century has been 31 bushels per acre.

It can be safely assumed that the increase in the yield from an average of 8 bushels in the fourteenth century to one of 27 bushels in the middle of the nineteenth century was a real improvement in the average yield per acre, due chiefly to an extended application of manures and more efficient cultivation of the soil.

Regarding the more recent advance of 3 or 4 bushels in the yield per acre during the last sixty or seventy years, there is less certainty in respect of its real character and cause. It is probable that the increase is not due to improvement in cultivation or general management, but to the fact that land which gave poor return has been utilised for other purposes, only that specially suited to wheat being retained for this crop. Under such circumstances the average yield per acre would rise even if the manuring, cultivation, and seasons remained unchanged or were worse than before.

Real progress is only made when the increase in the yield per acre is obtained from the same area, and it is doubtful if any material improve-

ment has been made in this sense during the last half century or more in this country. There is much evidence that most of the good land was highly farmed seventy to a hundred years ago, and rarely gave less than 40 bushels per acre.

Moreover, in Great Britain the higher and lower limits of yields per acre during the last hundred and fifty years or more appear to have been much the same, records of 50 and 60 bushels per acre are frequent as far back as the middle of the eighteenth century, and Bradley in 1757 states that " the largest produce of an acre of wheat land, so far as has yet been experienced, seems to be 10 quarters or 80 bushels per acre," a yield which is rarely equalled at the present day.

Norden in 1607 observes that in Somersetshire on well-tilled good land " they have sometimes in some places 4, 5, 6, 8, yea, 10 quarters in an ordinary acre."

The largest yield per acre hitherto recorded in any part of the world upon a field of more than 1 acre is 117·2 bushels, which is given in the United States Monthly Crop Report for July 1918. The crop was grown in 1895 on a field of 18 acres in Island County, Washington, U.S.A., the soil being described as a black sandy loam overlying a clay subsoil. The variety of wheat was Australian Club. No manure had ever been applied to the land, and in the three previous seasons potatoes were grown on the field.

In 1918, Mr. Alfred Amos of Wye, Kent, obtained a yield of 96 bushels (63 lbs.) per acre of " Yeoman " wheat on an area of about 3½ acres. The seed was sown on November 20, 1917. The soil of the field is a deep rich loam overlying 6 feet of brick earth. No fertiliser was applied to the wheat crop, but the previous crop of beetroot was well manured.

Morton (*Journ. Royal Agric. Society*, 1859) reports a yield of 90 bushels per acre obtained in 1844 on a field measuring 5¼ acres in the parish of Haisborough in Norfolk.

The wheat grown was " Spalding," sown in the autumn of 1843 at the rate of 3 bushels per acre.

Land almost adjoining gave 80 bushels per acre in the same season.

The lower limits of the yield of wheat as ordinarily grown in Great Britain are 10 or 12 bushels per acre, returns of this amount being not infrequent during the last hundred and fifty years.

The yield per acre is dependent upon a very large number of factors. Some of them cannot be altered by the farmer, while others are within his power to modify and control.

To the former class belong climate, season, and original physical and chemical condition of the soil ; among the latter are drainage, cultivation, and manuring of the soil, the yield per ear and the number of ears grown per acre.

Climate.—That an adequate temperature, a certain light intensity, and a suitable supply of water are essential conditions for the growth of all crops is well understood, but the influence of variations in each of these factors upon the yield of the wheat crop has not been exactly investigated.

The highest yields of wheat are only obtained in districts where the mean winter temperature is comparatively high, the rainfall 20 to 30 inches during the growing season, and bright warm weather at the time of the development and ripening of the grain.

It is well known among the agriculturists of this country that an excessive rainfall during the winter is disastrous to the yield of autumn-sown wheat, and especially so where the sowing has been delayed. The root-system and the young shoots of the plants are seriously checked in their development, doubtless by the want of adequate aeration of the water-logged soil and the loss of soluble food constituents in the drainage.

It has been remarked by many observant farmers of the last two centuries that upon the same farm in one season the yield per acre has sometimes been 30 bushels, while in other seasons upon the same fields with similar cultivation, manuring, and general treatment of the crop, the return has been less than 20 bushels.

In Great Britain the best season of last century was 1863, when the wheat crops throughout the country were extraordinarily good: the worst was 1879, when the yield was estimated at less than half the average.

The difference between these seasons is strikingly illustrated by the returns, given below, of the wheat crop upon several plots at Rothamsted which have received the same manures and general cultivation annually for over sixty years.

YIELD OF GRAIN PER ACRE

Plot.	Manures.	Best Season (1863).	Worst Season (1879).	Difference.	Average 61 Years (1852–1912).
		bushels.	bushels.	bushels.	bushels.
3	No manure	17¼	4¾	12½	12·6
2	Farmyard manure	44	16	28	35·2
5	Mixed mineral manures	19⅝	5⅝	14	14·5
6	Do. NH_4 salts (43 lbs. N)	39⅝	10½	29⅛	23·2
7	Do. NH_4 salts (86 lbs. N)	53⅝	16¼	37⅜	32·1
9	Do. nitrate of soda (86 lbs. N)	55⅝	22	33⅝	..
8	Do. NH_4 salts (129 lbs. N)	55¾	20⅝	35⅛	36·6

In 1863 the winter and early spring were extremely mild, with a rainfall below the average. In the growing season of the early summer there was abundant rain, followed by dry weather in June and July up to harvest.

In the season of 1878–9, from the 22nd of October to the first week of December, the weather was cold and wet. The five months ending March 31 were cold with much snow and rain, and from April to July the days were cold and wet with little sunshine. Lawes states that it was the worst season experienced in Great Britain since 1816.

Examination of the annual yields shows that even on the exhausted plot which has carried wheat for sixty years without manure the impress of a favourable season is very marked by a distinct increment, which in 1863 amounted to more than 4 bushels per acre. Perhaps more remarkable is the fact that in the best season, plot 7 gave 53 bushels per acre, while the application of the same amount of manure to this plot in 1879 resulted in the production of only 16 bushels.

Thus it is evident that season is of far greater import than any other factor in determining yield: cultivation and manuring are of little avail when the climatic conditions are unfavourable.

So far as this country is concerned the average annual temperature is usually too low for the best development of the wheat plant, but reduced yields of the grain are attributable to the high rainfall rather than to the low temperature.

The relation between the average yields in England during the twenty-one successive years 1884–1904, and the total rainfall for the three autumnal months, October, November, and December, was investigated by Shaw, who found that a close approximation to the actual returns at harvest is given by the formula:

Yield per acre $=39\cdot5$ bushels $-\frac{5}{4}$ of the rainfall (expressed in inches) of the previous autumn. In years of high yield the autumnal rainfall is considerably below the average, in bad seasons it is excessive.

The importance of rainfall is seen in the following Rothamsted returns:

	Average of Ten Wettest Winters.	Average of Ten Driest Winters.
Rainfall (November-February inclusive)	inches. 13·01	inches. 5·79
Average yield per acre of plots 6, 7, and 8	bushels. 26·2	bushels. 34·9

Soil.—Although wheat will grow upon almost all kinds of soil from the heaviest clays to the sands and gravels, the highest yields are only obtained upon rich, deep, well-drained loamy clays, the physical character of which is fairly uniform down to a depth of 2 or 3 feet.

Upon clays, especially if imperfectly drained, the yields are constantly smaller, as they are also upon the light sands, gravels, and peaty

soils, which require the application of much manure and careful cultivation before they will give remunerative returns of this cereal.

Cultivation and Manuring.—The influence of cultivation of the soil and the manuring cannot be discussed here: they are nevertheless important factors in determining yield. Early ploughing in order to sow on a stale furrow is a maxim followed by all farmers who obtain the best yields of wheat.

With this cereal as with all other crops the application of suitable manures improves the returns.

For the highest yields the soil should be rich in phosphates and potash and well supplied with available nitrogen.

The two former elements are often obtained from the residues of fertilisers used for the previous crops rather than from direct application to the wheat plant, although the addition of superphosphates and kainit may be profitably employed where the land is in poor condition. The nitrogen is frequently obtained from the residue left by leguminous crops, but the application of nitrate of soda or sulphate of ammonia to the plant in spring is generally practised where heavy crops are obtained.

Amount of Seed.—The amount of seed sown has a large influence upon the yield per acre, for upon it depends, in measure, the number of ears which are produced, and it is these and the grains which they bear which determine the yield.

In countries where the rainfall is low, the growing season short, and the yield necessarily limited, the amount sown is often less than 1 bushel. In Australia 40-60 lbs. per acre is general, and in many parts of the United States 45-60 lbs. are often sown.

In Western Europe, with its higher rainfall, better cultivation, and expected yield of 30 bushels or more per acre, very much larger quantities are sown, the amount varying between 2 and 4 bushels (126-252 lbs.) per acre.

About 2 bushels per acre were recommended by the ancient Roman agriculturists, Varro and Columella, and this quantity has been in general use in Great Britain, apparently from the time of the Roman occupation to the present day.

Since the seventeenth century it has been the practice to increase the seed sown, 2 bushels being found insufficient in many instances to provide the best number of plants or ears for a good crop of grain.

On land in a high state of fertility in a warm district, 2 bushels is sufficient to produce a thick enough "plant" for the production of a maximum crop. Where the soil is infertile, dry or cold, and in districts in which adverse climatic conditions prevail, the amount is increased with advantage up to 3 or 4 bushels per acre.

When fixing the amount of seed to sow, it is necessary also to take into

consideration the variety of wheat, the time and method of sowing, and the average size of the seed.

Variety.—There are very considerable differences among wheats in regard to their grain production under the same soil and climatic conditions. This is chiefly due to the difference in the length of their growing period. Many of the rapid-growing short-lived spring varieties complete their life-history in 95-120 days. On the other hand, some of the winter wheats require 180-200 days for their growth. The latter produce more stems, leaves, and ears, and usually yield not less than 25 per cent more grain than spring varieties on the same land.

Even among spring and winter varieties certain forms are found to be more efficient than others when grown under the same conditions. For example, it is generally believed that Marquis wheat produces more grain than many other spring forms on most of the spring wheat-growing areas of the American continent, and among winter wheats in Western Europe the Squarehead types almost invariably give higher yields than any of the lax-eared forms.

Time of Sowing.—There are two periods at which wheat is generally sown, namely (1) autumn and (2) in spring. On account of the longer growing period allowed by autumn sowing, the yield is invariably higher for wheats sown at that time than after winter. The autumn-sown plants are already established and possess several shoots before the later-sown plants make a start, and this advantage is never lost.

The loss varies with the kind of wheat, the deficiency being least in the case of the spring wheats, whose growing period is naturally short, and greatest in the winter wheats, which require a long period for their highest development.

Where the sowing of autumn wheats is delayed until February or March there is generally a loss in yield of not less than 15-20 per cent, and on land in poor condition it may amount to as much as 50 per cent.

At the College Farm, Reading, forty kinds were sown on October 21, 1910, and again on February 9, 1911. In all the varieties there was a loss of yield of grain through sowing at the later date: the percentage deficiency of a few showing the greatest and least variation are given below:

	Loss per cent.		Loss per cent.
Red Dantzig	55	Sicilian	30
Chidham	49	Hungarian	28
Noë	49	Japanese	26
Partridge	46	Talavera	17
Red Nursery	44	March	14
Golden Drop	37	Fern	11
Swan	37	Californian	10

The average yield of grain per ear of plants from seed sown in autumn was 1·45 gr., the ears of the spring-sown plants averaging ·99 gr. of grain.

Many of the spring varieties tillered better when sown in February than they did when sown in October.

Not only is there a difference between autumn and spring sowing, but there is a progressive decrease in the yield with every week's delay in sowing from October to December.

The advantage of early sowing is seen in the following results of trials at the Harper Adams Agricultural College with Browick (=Squarehead) wheat.

Time of Sowing.	Yield per Acre.	
	Grain.	Straw.
	bushels.	cwts.
September 30, 1916 . . .	34·00	43
October 13, 1916	30·16	39
November 6, 1916 . . .	23·96	36

The results obtained from wheat (Swan) sown on the 1st and 15th of each month throughout the year 1915 and first three months of 1916 are given on page 424 (Fig. 227).

The "tillering" or number of ears decreases more or less regularly the later the grain is sown from May onwards to March of the following year.

The average weight and length of the ears and the number of spikelets are highest in plants obtained from grain sown in October and November; in earlier and later-sown plants these diminish.

The maximum average height of the straw is found in plants from grain sown in September.

Although the number of ears per plant is greater when the grain is sown before September, the ears are larger and contain a greater amount of grain when the seed is sown in September, October, and November, just those months in which it has been the practice of the farmers of this country to sow their autumn wheats from the earliest times.

Which of the three months just mentioned gives the best returns in particular cases depends upon a number of circumstances, such as the physical and manurial state of the soil, aspect, altitude, and other conditions. Whatever the time, it is important that the seed should be sown in dry weather.

Generally speaking, the earlier the sowing the better the yield, especially in late districts and where the soil is comparatively poor. The

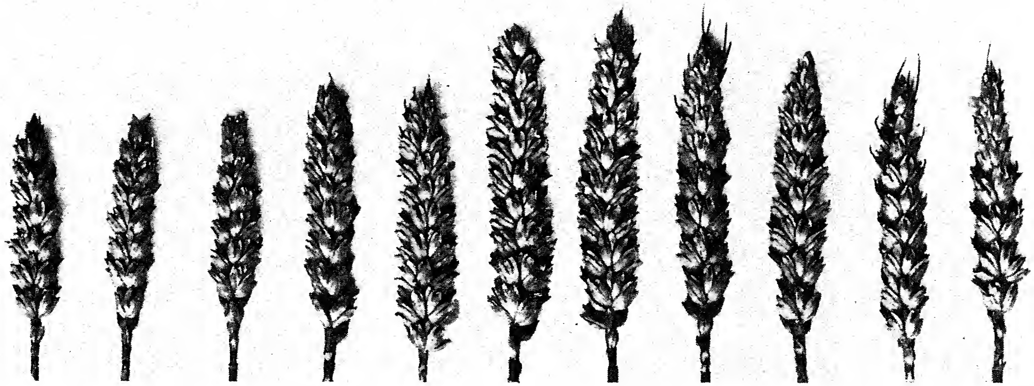


FIG. 227.—Average ears of "Swan" wheat from plants grown from grain sown on the 1st and 15th of each month (1915–16).

	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.
Average weight of one ear (gr.)	1·33	1·33	1·15	2·11	2·19	2·40	2·53	2·19	2·07	2·07	..
No. of spikelets per ear . .	18·2	18·2	..	20·7	21·3	21·6	21·9	21·2	20·7	20·0	18·8
Length of ear (cm.) . . .	7	6·8	6·7	8·3	8·5	9·4	9·7	8·9	8·9	8·8	8·1
Height of straw (cm.) . .	110	115	120	130	135	130	120	115	107	95	80
No. of ears per plant . .	13·3	18·7	12·1	13·7	8·2	7·0	8·7	6·5	6·7	5·2	5·6

greatest area is sown in October, but in the warmer southern parts of Great Britain, on well-drained soils in high condition, sowing in the first half of November is often practised and gives good results. In such districts if the grain is sown earlier the plants are liable to become "winter proud," or too luxuriant in spring, a condition which frequently leads to the "lodging" of the crop before harvest.

Methods of Sowing.—Three methods of sowing are in use, namely, (1) broadcasting, (2) drilling, and (3) dibbling. The system of scattering the seed broadcast by hand is the most ancient method, and is still practised wherever wheat is grown. It is a rapid method but involves the use of more seed than the other methods.

Drilling in rows, first introduced by Jethro Tull towards the middle of the eighteenth century, has now almost entirely superseded the broadcast system. Less seed is needed, and all the seed is deposited at a fairly uniform depth in the soil when this method is adopted. Moreover, it allows of the hoeing and cleaning of the crop during growth, and on this account leads to a larger yield per acre than the broadcast system in which the weeds remain unchecked.

Where the land is in a clean state and in a high state of fertility both methods of sowing give similar results.

Dibbling, or depositing the seed by hand in holes made in the soil by a blunt-pointed tool, had its advocates in former times. The holes were made in rows 5-9 inches apart, and 3-5 inches asunder in the rows, and two or three grains were dropped into each hole. Six to seven pecks of seed were used, the work being carried out by the labourer and his children.

Size of Grain.—The influence of the size and weight of the individual grains upon the size of the plants which they produce and the amount of grain which these yield has often been the subject of research.

The average weight of 100 grains of Bread Wheat varies considerably. In some forms it is not more than 3·5 grams, with a maximum near 4·7 grams and a minimum of 1·6 grams; others, especially those commonly grown in this country at the present time, have an average weight of about 4·5 grams per 100 grains, with a maximum over 5 grams.

Peters in 1721 states that, in his day, in an ounce of good average wheat there were about 700 grains, the best numbering 600, the smaller samples 800 per ounce: these figures correspond with a weight of 4·05 grams per 100 grains of average wheat, 4·72 grams for the best, and 3·54 grams for the smaller grains.

In 1911 I selected ten large and ten small grains from a single ear of several kinds of wheat, the average weight of each large grain being ·05 gram, that of the small grains less than half or ·025 gram. The average

yield of grain of the plants produced by these selected grains was obtained, the experiment being repeated for five successive years.

The plants were grown in rows 6 inches apart and 3 inches asunder in the row. The results are given below:

	Ears per Plant.		Average Length of Ear (cm.).		Weight of Grains per Ear (grams).		Average No. of Grains in 10 Grams.		Average Yield of Grain per Plant (grams).	
	From Large.	From Small.	From Large.	From Small.	From Large.	From Small.	From Large.	From Small.	From Large.	From Small.
					PARTRIDGE WHEAT					
1911–12	4·0	3·0	..	..	1·51	1·54	227	216	6·0	4·6
1912–13	12·3	11·0	..	..	3·44	3·11	148	190	42·5	34·7
1913–14	11·1	4·7	9·0	9·1	2·30	2·00	241	241	25·6	9·2
1914–15	10·5	9·4	10·2	10·2	2·02	1·72	275	297	21·2	16·2
1915–16	13·1	11·3	9·7	9·1	1·13	1·37	260	279	14·8	15·5
Average	10·2	7·9	9·6	9·5	2·08	1·95	230	245	22·0	16·0
Percentage increase of large over small	29·1	..	1·05	..	6·6	..	..	..	37·5	..
					FOX WHEAT					
1911–12	6·0	3·0	..	..	2·20	1·46	218	249	13·2	4·4
1912–13	14·9	10·4	..	..	1·97	2·13	200	212	29·3	22·1
1913–14	10·2	7·6	9·7	9·3	1·85	1·70	255	265	19·0	13·1
1914–15	12·1	8·3	11·7	11·3	1·63	1·96	270	265	19·8	16·3
1915–16	13·1	11·8	10·4	10·1	1·07	·84	265	276	14·0	9·9
Average	11·3	8·2	10·6	10·2	1·74	1·62	242	253	19·1	13·2
Percentage increase of large over small	37·8	..	3·9	..	7·4	..	..	..	44·7	..
					SHIRREFF'S BEARDED WHEAT					
1911–12	9·0	5·0	..	..	1·78	2·18	200	191	16·0	10·9
1912–13	10·8	9·0	..	..	1·74	1·82	218	189	18·7	16·4
1913–14	5·4	4·0	7·4	7·3	1·83	1·55	240	289	10·0	6·2
1914–15	9·2	5·4	9·9	9·4	1·64	1·15	324	355	15·2	6·2
1915–16	8·6	5·8	8·3	8·2	·73	·78	266	297	6·3	4·5
Average	8·6	5·8	8·5	8·3	1·54	1·50	250	264	13·2	8·8
Percentage increase of large over small	48·3	..	2·4	..	2·7	..	..	..	50	..

From these results it is seen that the average lengths of the ear and the average weights of the grains per ear of plants produced from the large grains are but slightly greater than those of the progeny of small grains, and the difference may not be significant.

The number of ears per plant and the average yield per plant is, however, very much greater every year from the large seed than from the small, and the difference in vigour was manifest throughout the whole life of the plants.

Zavitz carried out experiments with large and small wheat grains for six years with winter wheats and eight years with spring wheats, and found an average annual increase of 6·5 bushels per acre from large as compared with small grains in the winter wheats, and 3·7 bushels increase in the spring wheats.

Similar pre-eminence of large over small seed grain has been observed by others.

The plants from small grain are weak, and many succumb to the adverse soil and climatic conditions of autumn and winter.

In a few exceptional instances, where the land has been in a specially high condition, small seed grain has given remunerative results almost equal to those in which larger seed has been sown; nevertheless the inferiority of small grain as seed is always strikingly evident when its yields are compared with those from large grain upon soil in comparatively poor condition.

Number of Grains sown.—The number of grains in a bushel (63 lbs.) of Bread Wheat varies between 500,000 and 800,000.

In the former case the grains are large, 100 weighing 5·71 grams, 100 of the latter weighing 3·57 grams. The number of grains in a bushel of wheat of the type usually grown in this country is about 650,000, 100 weighing 4·4 grams.

From the following table it is seen that when one bushel of an average sample is used there are sown about 134 grains per square yard, the rate when 3 bushels are sown being 392 per square yard.

NUMBER OF GRAINS SOWN PER ACRE

(100 grains = 4·4 grams).

Bushels.	Number per Acre.	Number per Square Yard.
1	650,000	134
1½	975,000	201
2	1,300,000	268
2½	1,625,000	336
3	1,950,000	392

Even under favourable conditions the number of plants which appear above ground after sowing these amounts of grain are generally 5-10 per cent less than the figures quoted, since the germinating capacity of the seed wheat is usually not more than 90-95 per cent.

Not infrequently 15-30 per cent of the plants which are seen soon after the seed germinates disappear later. This decrease is due to destruction by birds, insects, and fungi, as well as by frost and adverse conditions of the soil. Some of the loss is also brought about by competition

among the young plants and the deleterious effect which one plant has upon another even of the same species when grown together. In Montgomery's experiments the death-rate among wheat plants, grown in rows 8 inches apart and $\frac{1}{4}$ inch asunder in the row, was 23-38 per cent, the loss being 12-25 per cent among the less crowded plants growing $1\frac{1}{2}$ inches asunder in the rows.

The number of plants which survive until harvest under ordinary field culture has rarely been determined, but the number of ripe ear-bearing straws has been frequently counted, the number per acre ranging from about 150 to 400 per square yard, where $2\frac{1}{2}$-3 bushels of grain have been sown. In many instances there are fewer straws with ears than grains sown, owing to the high death-rate among the plants.

It is found that a good crop is rarely obtained in this country where the number of ears is less than about 300 per square yard.

Not only is the number of ears per acre significant, but the number and weight of the grains in each ear is of the greatest importance, and efforts to increase the yield per acre are usually directed towards improvement in this respect.

The total yield of an ear is dependent upon the number of its spikelets and the number of grains developed in each spikelet.

The average number of spikelets in an ear of Bread Wheat (*T. vulgare*) is about 20, but it differs, though not very widely, in different varieties and forms, some having an average of 18, others 22 or 23 per ear.

In Rivet wheats (*T. turgidum*) the average is higher, being about 25.

The number of flowers in a spikelet varies from 3 to a possible 8 or 9, but many of the upper flowers prove abortive, the number of grains which develop varying from 1 to 7, the latter number being only met with in the spikelets of ears borne upon plants which have been exceptionally manured (Fig. 228).

Well-grown ears of the field often bear 5 or 6 grains in each of the 3 or 4 median spikelets, the numbers falling gradually to 1 or 2 in the basal and apical spikelets.

Many of the spikelets at the base of smaller ears are abortive, the number of these increasing with adverse climatic conditions, poverty of the soil, and excessive tillering of plants sown earlier than September.

The largest ears of an ordinary field crop in this country frequently possess 40 to 50 grains, weighing from 1·8 to 2·25 grams, the smallest not more than 12 or 14 grains, weighing ·54-·63 grams, an average ear having from 25 to 30 grains, weighing 1·25 to 1·35 grams.

In the following table are given the calculated yields per acre, when the number of straws varies between 50 and 400, and the yield per ear between ·5 gram (12 grains) and 3 grams (72 grains).

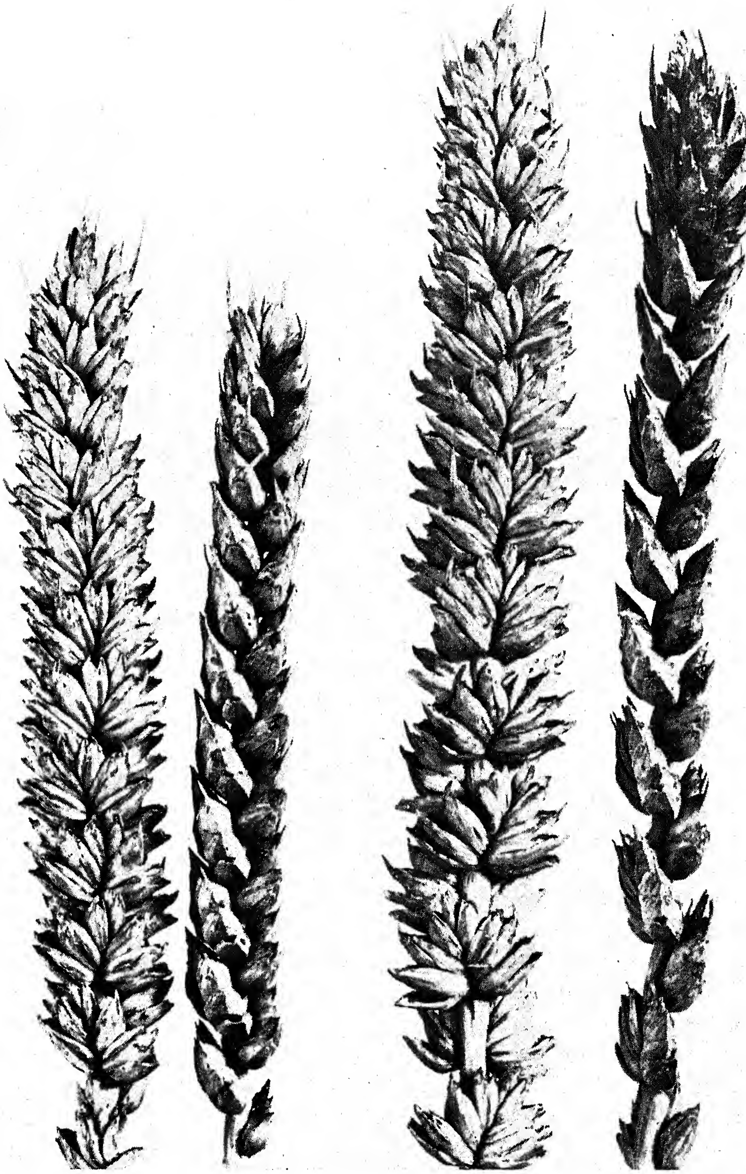


Fig. 228.—Ears of "Swan" Wheat.

1. Normal ears. 2. Ears of plants excessively manured with nitrates, phosphates, and potash.

TABLE OF YIELD PER ACRE IN BUSHELS (63 lbs.) WITH VARYING EAR WEIGHT AND NUMBER OF EARS PER SQUARE YARD

(100 grains = 4·166 grams).

No. of Ears per Square Yard.	Yield per Ear.				
	·5 Gram (12 grains).	1·0 Gram (24 grains).	1·5 Grams (36 grains).	2·0 Grams (48 grains).	3·0 Grams (72 grains).
	bushels.	bushels.	bushels.	bushels.	bushels.
50	4·23	8·46	12·69	16·92	25·38
100	8·46	16·92	25·38	33·84	50·76
150	12·69	25·38	38·07	50·76	76·14
200	16·92	33·84	50·76	67·68	101·52
250	21·15	42·30	63·45	84·60	126·90
300	25·38	50·76	76·14	101·52	152·28
350	29·61	59·22	88·83	118·44	177·66
400	33·84	67·68	101·52	135·36	203·04

The amount of seed which should be sown in order to obtain the most productive return has been settled by experience long ago in most of the wheat-growing regions of the world.

In this country, as already mentioned, the amount lies between 2 and 4 bushels per acre.

In almost every generation, however, during the last two centuries there have arisen thin-seeding advocates, who recommend the use of very much smaller quantities of seed. Some of them refer to the sowing of 2½-3 bushels as "a barbarous system," and give evidence of records of 40 bushels per acre after sowing one peck (15-16 lbs.) or less per acre in drills 8-9 inches apart, the grain in the rows being on an average 4-5 inches asunder.

From an examination of such cases it is seen that the land is especially suited to the growth of wheat, and is in a high state of fertility and free from weeds, conditions which lead to extensive tillering of the plants.

Experience has shown that on most of the wheat land in England there is great risk in sowing less than 2 bushels per acre, and although the success of these exceptional examples may lure the farmer to give thin-seeding a trial, the practice is swiftly abandoned, for upon unsuitable soil the experiment is a disastrous and total failure.

The extraordinary prolificacy of the wheat plant attracted attention in early times.

Everard in 1692 (Houghton's *Husbandry*) states that he obtained from single grains sown 10 inches apart, plants which produced 60-80 ears, the largest of which contained 40-60 grains, the best plants yielding over 4000 grains.

Tull in 1731 refers to plants with 40 ears. In 1870 C. H. Shirreff

found in his garden a single plant bearing 80 ears, which yielded 4524 grains, and I have had plants bearing 60-70 ears and over 2500 grains.

Many other examples might be given of the enormous number of grains which can be obtained from the sowing of one.

In all these examples the plants were grown on soils in a high state of fertility and had unrestricted space for their development.

The most important limiting factors in these high returns of single plants is the space upon which they are grown, and the extent of the soil through which the roots can freely penetrate without competition from other plants.

These factors are frequently overlooked in discussing methods of improving the yield per acre by the growth of exceptional plants.

The necessary space required to secure these highly productive plants is not known, but it is certain that it is vastly greater than 10 square inches, the space which is allotted to each grain when one bushel (650,000 grains) is sown on an acre.

In the table below, from a single grain sown on the most widely spaced plot 354 grains were produced, and from 1 bushel of similar grains 354 bushels would be obtained; nevertheless, since each plant was allotted 4 square feet, to secure 354 bushels from such plants an area of nearly 60 acres would be needed. In other words, the yield is less than 6 bushels per acre, although the statement that the return was 354 grains or bushels for one sown appears exceptionally large.

Similarly the statements made by some thin-seeding enthusiasts that they had experienced "a return of 500 for 1 on an acre," and "804 for 1 on a plot of 700 square feet," are no indications either of good or bad yields per acre, for the statements apply equally to 1 grain, 1 pound, or 1 bushel sown per acre or plot.

With increasing space the number of ears per plant and the number of grains in each ear rises rapidly.

Below are given the results of the growth of plants of Swan wheat (*T. vulgare*) produced from grains sown at varying distances apart, the smallest space allotted to each plant being 6 square inches, the largest 576 square inches.

TABLE I

Space allotted.	No. of Plants per square yard.	No. of Ears per Plant.	No. of Grains per Ear.	No. of Grains per spikelet.	No. of Grains per Plant.	Weight of Grains per Ear.	Total weight of Grain per Plant.	Bushels (63 lbs.) per acre.
inches.						grams.	grams.	
6 × 1	216	1·61	27·1	1·44	43	1·14	1·18	43·15
6 × 3	72	1·52	32·6	1·69	50	1·48	2·25	27·43
6 × 6	36	1·82	34·6	1·66	63	1·58	2·87	17·49
12 × 6	18	2·92	43·3	1·89	126	1·88	5·49	16·73
12 × 12	9	4·04	48·1	2·10	194	2·08	8·40	12·80
24 × 24	2·25	7·03	50·3	2·16	354	2·14	15·04	5·73

Montgomery gives the following results of experiments upon the rate of seeding and yield in an American winter wheat sown in rows 8 inches apart and $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, 1, and 2 inches asunder in the rows.

TABLE II

Area allotted to each Plant.	No. of Plants per Plot.	Yield of Grain per Plant.	Total Yield per Plot.	Yield per Acre.
inches.		grams.	grams.	bushels (63 lbs.).
$8 \times \frac{1}{4}$	238	·91	259	45·3
$8 \times \frac{1}{2}$	217	1·36	159	41·2
8×1	204	2·58	79	38·7
8×2	165	4·10	40	31·6

The relationship between tillering and yield per acre is of a complicated nature. So far as the yield of the individual plant is concerned, the more it tillers the greater the return in grain and straw. Moreover, when sown at the normal time in autumn or spring the more highly tillered the plants the greater the average weight of the ears, although when the tillering is excessive through sowing abnormally early the average weight of the ears decreases. These conclusions are evident from the table above, and from the results given on page 424 (Fig. 227).

The number of straws or ears and the average weight of the ears are the factors controlling the yield per acre.

With thick sowing the number of ears per acre increases, but the weight of the individual ears decreases. A thinly sown crop in which the same number of straws are present as in one thickly sown gives a higher yield on account of the fact that tillered plants have a higher average weight of ear.

Nevertheless, if the number of grains is much less than that ordinarily sown the increased number of straws per plant and the greater average weight of each ear do not compensate for the loss of plants which thin sowing entails.

Thus tillering may result either in an increase or a decrease in the yield per acre when compared with a crop in which each plant has produced but a single ear on account of being thickly sown.

While increased tillering leads to the production of more straw *per plant*, the number of straws per acre decreases with tillering, a paradoxical statement which depends for its truth upon the fact, that the smaller the number of plants the greater the tillering; at the same time this does not compensate for the loss of plants incurred by thin-sowing.

In Table I. there is seen a rise of the yield per acre as the plants become closer from 24 inches × 24 inches down to 6 inches × 1 inch.

In spite of the fact that under special circumstances thin-sowing may succeed, in practice it is found to be less hazardous to attempt to obtain an adequate number of ears per acre by thick-sowing rather than by thin-sowing and its concomitant tillering, especially when the amount of seed sown is far removed from that ordinarily sown.

Proportion of Grain to Straw and Proportion of Grain to Chaff.—The ratio between the weight of the grain and that of the straw of the wheat plant varies very much with the variety, the space allotted to the plants, and their nutrition.

As ordinarily grown in the field the average proportion is usually 32-36 per cent of grain to 68-64 per cent of straw, but large amounts of farmyard manure or nitrogenous fertilisers stimulate the production of leaves and stems and reduce the proportion of grain to straw.

Plants grown at wide intervals show a different ratio.

Of seventeen common forms of Bread Wheat grown in rows 1 foot apart, the plants 6 inches asunder in the rows, the highest proportion was 47 per cent of grain to 53 per cent of straw, the lowest 33 of grain to 67 of straw.

The proportion of the weight of the grain to that of the rest of the ear (chaff and rachis) in a beardless wheat whose ears (500) were selected at random from the field was 66·6 per cent of grain to 33·3 of chaff and rachis, or 2 of grain to 1 of chaff.

In ears of plants grown 6 inches apart the proportion of grain was higher, reaching in a number of cases a ratio of 75-78 per cent of grain to 25-22 per cent of chaff, *i.e.* between 3 or 4 of grain to 1 of chaff.

LIST OF WHEATS

di. = *T. dicoccum.* | *du.* = *T. durum.* | *t.* = *T. turgidum.* | *v.* = *T. vulgare.* | *sph.* = *T. sphaerococcum.*
o. = *T. orientale.* | *po.* = *T. polonicum.* | *py.* = *T. pyramidale.* | *c.* = *T. compactum.* | *Sp.* = *T. Spelta.*

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Ablakh	*v. Hostianum*	Persia
Abundance	*v. alborubrum*	Canada
Abyssinian Purple = Tukur Sinde	..	..
Admiral, Red	*v. lutescens*	England
Agh Bogda	*v. graecum*	Persia
Akabozu	*v. lutescens*	Japan
Aka yenidashi	*v. ferrugineum*	,,
Ak Bashak	*t. gentile*	Turkey
,,	*v. meridionale*	,,
Alaska	*t. pseudocervinum*	U.S.A.
Aleph	*v. lutescens*	France
Alexandre	*du. africanum*	Portugal
Alfaro, de	*du affine*	Spain
Alonso fanfarron	*du. leucomelan*	,,
Altkirch rouge	*v. milturum*	France
Amarella barba branca	*du. affine*	Portugal
Amarella barba preta	*du. melanopus*	,,
Amber, Egyptian	*v. erythrospermum*	U.S.A.
,, Imperial	*v. ferrugineum*	,,
,, Martin's	*v. albidum*	,,
American Banner	*v. alborubrum*	,,
Amidonnier	*di.*	France
Anafil	*du. melanopus*	Portugal
,,	*du. africanum*	,,
Andaluze	*du. melanopus*	,,
Andriolo rosso	*t. dinurum*	Italy
Anti-fly	*t. buccale*	England
April Fern	*v. ferrugineum*	,,
Arctic Junior	*v. ferrugineum*	U.S.A.
Arnautka	*du. hordeiforme*	Russia
Arnovka	,,	,,
Asa de Corvo	*du. libycum*	Portugal
Aurora	*v. Hostianum*	Canada
Australian White	*v. albidum*	U.S.A.
Azulejo	*du. obscurum*	Spain
Badger	*v. erythrospermum*	England
Baladi	*du. leucurum*	Asia Minor
Banat	*v. erythrospermum*	Hungary
Bansi	*du. apulicum*	India
Barbarusa	*v. ferrugineum*	Spain
Barbella	*v. erythrospermum*	Portugal
Barbu à gros grain	,, ,,	France
Barletta	*v. ferrugineum*	Argentina
Baroota Wonder	*v. albidum*	Australia
Bascuñano	*du. erythromelan*	Spain
,,	*du. alexandrinum*	,,
Bayah	*v. alborubrum*	Australia
Beechwood Hybrid	*v. milturum*	U.S.A.
Beloglena	*v. erythrospermum*	,,
Beloklassa zagani	*du. Valenciae*	Bulgaria
Belokoloska	*v. erythrospermum*	Russia
,,	*v. lutescens*	,,
,,	*du. hordeiforme*	,,
Belotourka	,,	,,
Benefactor	*v. leucospermum*	England
Berberisco	*du. erythromelan*	Spain
Bianchette	*v. alborubrum*	Italy
Bianco	*du. leucurum*	,,
Biancone	*t. gentile*	,,
Bishop	*v. albidum*	Canada
Blanc à paille raide	*v. albidum*	France
Blanc velouté	*v. leucospermum*	,,
Blanco verdeal	*du. leucurum*	Spain
Blanquillo	,,	,,

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Blaue Dame	*v. lutescens*	Germany
Blé à épi carré =Squarehead	..	France
Blood Red	*v. milturum*	Scotland
Blue Cone	*t. iodurum*	England
Blue Ridge	*v. ferrugineum*	U.S.A.
Blue Stem, Haynes	*v. velutinum*	,,
Blue Stem, Palouse	*v. albidum*	,,
Blue Velvet Chaff	*v. cyanothrix*	Germany
Bobs	*v. albidum*	Australia
Bobs Red	*v. lutescens*	Canada
Bomen	,,	Australia
Bon Fermier	,,	France
Bordeaux	*v. milturum*	,,
Bordier	*v. albidum*	,,
Bore	*v. lutescens*	Sweden
Branco	*t. lusitanicum*	Portugal
Briquet Jaune	*v. lutescens*	France
Brodie's White =Oxford Prize	..	..
Browick	*v. milturum*	England
Browick White =Squarehead	..	,,
Buda Pesth	*v. erythrospermum*	U.S.A.
Budd's Early	*v. alborubrum*	Australia
Buisson	*t. nigrobarbatum*	France
Bunge	*v. albidum*	Australia
Bunyip	,,	,,
Burgoyne's Fife	*v. albidum*	England
Burwell Red	*v. milturum*	,,
Bushak	*v. Delfii*	India
Caledon Baard	*v. erythrospermum*	S. Africa
Caliph	*v. albidum*	Australia
Canberra	*v. alborubrum*	,,
Candeal	*v. graecum*	Spain
Candial	*t. lusitanicum*	Portugal
Cannu altu	*du. leucomelan*	Spain
Canoco	*t. megalopolitanum*	Portugal
Canuto	*c. erinaceum*	Spain
Carbillo	*c. splendens*	Chili
Carman	*v. ferrugineum*	..
Carosello	*v. lutescens*	Italy
Carosellone del Molise	*t. melanatherum*	,,
Cascalvo	*du. affine*	Portugal
Catanzaro duro	*du. leucurum*	Italy
Cedar	*v. lutescens*	Australia
Ceres	*v. albidum*	England
Chacon	*du. leucomelan*	Spain

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Challenge	*v. albidum*	England
Chamorro	*v. alborubrum*	Spain
Champion	*v. lutescens*	Sweden
Champlain (Pringle's)	*v. erythrospermum*	U.S.A.
Champlan	*v. lutescens*	France
Chidham	*v. albidum*	England
,, de Mars	,,	France
Chile de fideos	*po. martinari*	Argentina
Chilian	*v. albidum*	..
,,	*c. Humboldtii*	..
Chul	*v. graecum*	U.S.A.
Claro	*du. leucurum*	Spain
Clawson, White	*v. albidum*	U.S.A.
Clawson, Early Red	*v. milturum*	,,
Clock	*t. dinurum*	England
Clover's Red	*v. milturum*	,,
Clubhead	*v. albidum*	Australia
Club, Little	*c. Humboldtii*	U.S.A.
College Eclipse	*v. alborubrum*	Australia
Colorado	*du. erythromelan*	Spain
Comeback	*v. albidum*	Australia
Comet	,,	S. Africa
Cone Rivet= Anti-fly	..	..
Crepi, de	*v. lutescens*	France
Criewener	,,	,,
Crimean	*v. erythrospermum*	U.S.A.
Cumberland	*v. albidum*	Australia
Currawa	,,	,,
Currel's Prolific	*v. milturum*	U.S.A.
Dantzig, Jersey	*v. albidum*	England
Dantzig Red	*v. alborubrum*	,,
Darling	,,	S. Africa
Dart's Imperial	*v. albidum*	Australia
Daruma	*v. ferrugineum*	Japan
Dattel	*v. alborubrum*	France
Dawson's Golden Chaff	,,	Canada
Defiance	*v. albidum*	U.S.A.
,, Paine's	*t. dinurum*	Germany
,, Pringle's	*v. albidum*	U.S.A.
,, Webb's	*v. lutescens*	England
Deitz	*v. erythrospermum*	U.S.A.
Del Frailte	*v. erythroleucon*	Spain
Diamond Grit	*v. erythrospermum*	U.S.A.
Dickkop	*v. albidum*	Holland
Dicklow	,,	U.S.A.
Dinkel	*Sp.*	..
Diozeg Banat	*v. erythrospermum*	Hungary

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Dividenden	*v. milturum*	Germany
Don, Black	*du. obscurum*	..
,, Velvet	*du. africanum*	..
Downy Kent	*v. leucospermum*	England
Dreadnought= Bon Fermier	..	..
Duckbill	*t. iodurum*	England
Dugdale	,,	,,
Durazio mollar	*du. melanopus*	Portugal
,, rejo	,,	,,
Du Toit	*v. albidum*	S. Africa
Early Baart	*v. graecum*	U.S.A.
,, Ripe	*v. milturum*	,,
Ecksteen	*v. graecum*	S. Africa
Eclipse=Red Admiral	..	..
Eggshell	*v. albidum*	England
Egypcio	*v. erythrospermum*	Azores
Egyptian Cone	*pyr.*	Egypt
,, Spelt	*di tricoccum*	,,
Ein el Bent	*pyr. copticum*	,,
Eley's Giant	*v. albidum*	England
Emmer	*di.*	..
,, Black	*di. atratum*	Germany
,, Red	*di. rufum*	,,
,, Slav	*di. farrum*	Russia
,, White	,,	Germany
Emperor	*v. albidum*	England
Enano de Lorca	*du. melanopus*	Spain
,, fuerte	,,	,,
Epautre	*Sp.*	France
Epp	*v. albidum*	Germany
Essex Conqueror =Squarehead	..	England
Essex Hybrid	*v. albidum*	,,
Essex Velvet Chaff	*v. leucospermum*	,,
Essex White	*v. albidum*	Australia
Fanfarron	*du. leucurum*	Spain
,, blanco	*du. fastuosum*	,,
Fanfarron, villoso raspinegro	*du. africanum*	,,
Fanfarron, villoso rubion	*du. italicum*	,,
Farmer's Friend	*v. albidum*	Australia
,, Trust	*v. ferrugineum*	U.S.A.
Federation	*v. alborubrum*	Australia
,, hard	,,	,,
Fenman	*v. lutescens*	England
Fenton	*v. albidum*	,,

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Fern=April Fern	..	England
Field-Marshal	*v. albidum*	Australia
Fife, Bearded	*v. erythrospermum*	U.S.A.
Fife, Bearded Winter	*v. meridionale*	,,
Fife, Burgoyne's	*v. albidum*	England
,, Crail	*v. velutinum*	U.S.A.
Fife, Jones' Winter	,,	,,
Fife, Power's	*v. milturum*	,,
,, Red	*v. lutescens*	Canada
,, White	*v. albidum*	,,
Filipino	*t. mirabile*	Spain
Firbank	*v. albidum*	Australia
Flandres, Blanc	,,	France
Florence	,,	Australia
Focense	*v. ferrugineum*	Spain
,,	*t. dinurum*	,,
Forte nero	*t. iodurum*	Italy
Fortyfold	*v. alborubrum*	Canada
Fourie	*v. graecum*	S. Africa
Fox	*v. ferrugineum*	Germany
,,	*v. pyrothrix*	England
Frankenstein	*v. albidum*	Germany
Frenisburg	*v. lutescens*	Switzerland
Fretes	*v. erythrospermum*	U.S.A.
Fucense	*v. ferrugineum*	Italy
Fultz	*v. lutescens*	U.S.A.
Galician	*v. lutescens*	..
Galland	*t. lusitanicum*	France
Gallego barbado	*v. ferrugineum*	Portugal
,, rapado	*v. milturum*	,,
Gallego rapado branca	*v. lutescens*	,,
Garagnon, Languedoc	*t. melanatherum*	France
Garagnon, noir	*t. Herrarae*	,,
Garnovka	*du. hordeiforme*	Russia
Gatinais, White	*t. gentile*	France
,, Red	*t. dinurum*	,,
Genesee Giant Early	*v. erythroleucon*	U.S.A.
Genoa	*v. albidum*	Australia
Gentile Bianco	,,	Italy
Ghirka, Red	*v. milturum*	Russia
,, White	*v. lutescens*	,,
Gironde	*v. lutescens*	France
Gluyas	*v. alborubrum*	Australia
,, Bearded	*v. erythroleucon*	,,
Gneisendorf	*v. lutescens*	Austria
Goldcoin	*v. alborubrum*	U.S.A.

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Golden Aue	*v. velutinum*	..
„ Ball	*du. hordeiforme*	S. Africa
„ Cross	*v. ferrugineum*	U.S.A.
„ Drop Red	*v. milturum*	England
Golden Drop White	*v. lutescens*	„
Golden Gem	*v. Delfii*	N. Zealand
Goose	*du. melanopus*	Canada
„	*du. Valencia*	„
Goose, Black = Nicaragua Black	..	..
Goose, Wild	*du. leucurum*	S. Africa
Granadino	*du. melanopus*	Spain
Granella de Carpegna	*v. lutescens*	Italy
Grano foote	*du. Reichenbachii*	„
„ nero	*t. iodurum*	„
Grenadier	*v. lutescens*	Sweden
Grimbeck's Klein Koren	*v. erythrospermum*	S. Africa
Gros bleu	*v. lutescens*	France
Grosse tête, Hybride	„	„
Guisano	*v. ferrugineum*	Spain
Gypsy	*v. erythrospermum*	U.S.A.
Hadmersleben	*v. lutescens*	Germany
Haie, de = Tunstall	..	France
Hallett's Pedigree White	*v. albidum*	England
Hardcastle	*v. milturum*	U.S.A.
Helena Hybrid	*v. ferrugineum*	..
Hembrilla	„	Spain
Hérisson, Bearded	*c. icterinum*	France
Hérisson, Beardless	*c. creticum*	„
Hickling	*v. lutescens*	England
Hickman	„	U.S.A.
Hindi	*v. graecum*	Egypt
Hoary, Old	*v. leucospermum*	England
Hochfeldt	*v. milturum*	Switzerland
Hogan, White	*v. albidum*	Australia
Hongrie Rouge	*v. milturum*	France
Hopetoun	*v. albidum*	England
Hosagara	*v. ferrugineum*	Japan
Hsu Hsu Mai	„	China
Hudavendigar	*t. dinurum*	Turkey
Huerta	*v. ferrugineum*	Spain
Huguenot	*du. australe*	Australia
Hundredfold	*v. milturum*	England
Hungarian	„	Argentina

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Hunter's White	*v. albidum*	England
Huron	*v. ferrugineum*	Canada
Imperial Buff	*v. velutinum*	England
„ Street's	*v. lutescens*	„
Invernanca	*v. ferrugineum*	Spain
Inversable rouge = Bordeaux	..	France
Iron	*v. lutescens*	Sweden
Ironclad	*v. erythrospermum*	U.S.A.
Ismaël	*du. Valencia*	France
Jade	*v. albidum*	Australia
Japhet	*v. lutescens*	France
„ White	*v. albidum*	S. Africa
Javardo	*du. libycum*	Portugal
John Brown	*v. alborubrum*	Australia
Jonathan	*v. albidum*	„
Jumbuk	*v. leucospermum*	„
Kadiz Oglou	*v. erythroleucon*	Turkey
Kalkori	*v. Delfii*	Persia
Kansas Mortgage Lifter	*v. erythrospermum*	U.S.A.
Kara Bashak	*du. coerulescens*	Asia Minor
Kar-i-safid	*v. turcicum*	Persia
Kent, Red	*v. milturum*	England
Kessingland	*v. lutescens*	„
Keupely	*t. pseudocervinum*	Turkey
Khapli	*di. Arras*	India
King's Red	*v. erythrospermum*	Australia
„ White	*v. graecum*	„
King William = Hickling	..	England
Kintana	*v. erythrospermum*	Japan
Kinver Red	*v. lutescens*	England
Kizildaly	*v. alborubrum*	Turkey
Koffoid	„	U.S.A.
Kostroma	*v. albidum*	Russia
Krasnokoloska	*v. ferrugineum*	„
Kubanka	*du. hordeiforme*	Russia
Kubb	*c. Wernerianum*	Sweden
„ Velvet	*c. Wittmackianum*	„
Kwang T'ou Mai	*v. milturum*	China
Ladoga	*v. ferrugineum*	U.S.A.
Lamed	*v. milturum*	France
Lammas, Red	„	England
„ White	*v. albidum*	„
Lancaster, Red	*v. erythrospermum*	U.S.A.
Leap Prolific	*v. lutescens*	„
Little Club	*c. Humboldtii*	England
„ Joss	*v. milturum*	„

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Lobeiro	du. affine	Portugal
Lofthouse	v. lutescens	U.S.A.
Loosdorf, Bearded	v. ferrugineum	Austria
Loosdorf, Beardless	v. lutescens	,,
Lucerna, de	v. ferrugineum	Spain
Lulea	v. velutinum	Sweden
Macolo	du. leucomelan	Spain
,,	du. melanopus	,,
Madonna	du. libycum	Germany
Mainstay	v. Delfii	England
Majestic	v. albidum	Australia
Major	,,	,,
Malakov	v. erythrospermum	U.S.A.
Mammoth Red	,,	,,
Manchester	v. albidum	..
March	,,	..
,, Bearded	v. erythrospermum	..
Mareuil, de	v. albidum	France
Mark Lane	v. albidum	England
Marouani	du. erythromelan	..
Marquis	v. lutescens	Canada
Mars rouge, barbu	v. ferrugineum	France
Mars rouge, sans barbes	v. milturum	,,
Marshall's No. 3	v. albidum	Australia
Martin	v. milturum	England
Marvel, Red = Bon Fermier	..	,,
Marvel, White	v. albidum	Canada
Marzuolo	v. ferrugineum	Italy
,,	du. Reichenbachii	,,
Massengo	v. erythrospermum	Italy
Massy	v. lutescens	France
Matador Rood Kop	v. alborubrum	Holland
Matador Wit Kop	v. albidum	,,
Mazzochio	t. speciosum	Italy
Medeah	du. erythromelan	Spain
Medeah Bald = Huguenot	..	Australia
Mediterranean	v. ferrugineum	U.S.A.
Michigan Amber	v. milturum	,,
,, Bronze	v. ferrugineum	,,
Milanaise, Geante de	t. dinurum	France
Million	v. albidum	Holland
Minnesota 169	v. velutinum	U.S.A.
Minuto d'Albona	v. ferrugineum	Italy
Miracle	t. mirabile	..
Mocho	c. creticum	Madeira
Model Red	v. lutescens	England
Mogul	v. alborubrum	Canada
Mold's Red Prolific	v. milturum	Germany
Monarch = Wilhelmina	..	England
Mongia	du. niloticum	Portugal
Montjuich	v. ferrugineum	Spain
Moro	v. ferrugineum	,,
Moula Oglou	t. Mertensii	Turkey
,,	t. Dreischianum	..
Mourisco vermelho	du. erythromelan	Portugal
Mullybrack	v. albidum	England
Mummy	t. mirabile	..
Mundi Pissi	v. albidum	India
Mungoswells	,,	Scotland
Murwarid	v. alborubrum	Persia
Muzaffarnagarh	v. graecum	India
Myburgh	v. erythrospermum	S. Africa
Nach Sinde	di. tomentosum	Abyssinia
Nanchero	v. milturum	India
Naples White	v. albidum	Spain
Negro de Camelas	du. apulicum	,,
New Zealand Long	v. ferrugineum	N. Zealand
Nicaragua Black	du. obscurum	S. Africa
Niekirks	v. ferrugineum	,,
Nigger	v. erythrospermum	U.S.A.
Nobbs	v. albidum	S. Africa
,,	v. alborubrum	,,
Noë	v. lutescens	France
Nonette de Lausanne	t. dinurum	,,
Nonpareil	v. alborubrum	England
Nursery Red	v. milturum	,,
Oakley, Extra Early	v. lutescens	U.S.A.
Obispado	du. affine	Spain
Odessa	v. alborubrum	,,
,,	v. albidum	..
Onega	v. ferrugineum	Canada
Onigera	,,	U.S.A.
Ontario, Early	v. albidum	,,
,, Wonder	v. lutescens	,,
Oregon Red	,,	,,
Ou-Baard	v. graecum	S. Africa
Oxford Prize	v. milturum	England
Partridge	v. lutescens	England
Pearl	v. leucospermum	N. Zealand

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Pellisier . .	*du. melanopus*	S. Africa
Pendulum = Rivet	..	England
Penny . .	*v. albidum*	Australia
Pera, La . .	*v. ferrugineum*	Spain
Perle de Nuisement . .	*v. erythroleucon*	France
Persian Black .	*di. persicum*	..
Pétianelle blanche	*t. lusitanicum*	France
Pétianelle noire de Nice . .	*t. iodurum*	,,
Peton . . .	*v. alborubrum*	Canary Isles
Phillipino . .	*t. nigrobarbatum*	U.S.A.
Phillipolis . .	*v. albidum*	S. Africa
Pilbeam . .	*v. milturum*	England
Pinet . . .	*du. erythromelan*	Spain
Pirkey . .	*v. lutescens*	England
Pisana blanca .	*t. gentile*	Spain
,, francesca.	*t. iodurum*	,,
Pithiviers . .	*v. milturum*	France
Plover . .	*v. lutescens*	England
Pole Rivet .	*t. iodurum*	,,
Pombinho . .	*t. buccale*	Portugal
Poole . . .	*v. milturum*	U.S.A.
Pooting Bearded	*v. ferrugineum*	,,
Portuguez . .	*du. leucurum*	Portugal
Potschefstroom .	*v. albidum*	S. Africa
Poulard blanc .	*t. gentile*	France
Poulard d'Australie .	*t. iodurum*	,,
Poulard de Gatinais . .	*t. speciosum*	,,
Poulard à six rangs	*t. gentile*	,,
Preston . .	*v. erythrospermum*	Canada
Prince Albert .	*v. milturum*	France
Pringle's Champlain . . .	*v. erythrospermum*	U.S.A.
Prizetaker . .	*v. alborubrum*	Canada
Probsteier . .	*v. lutescens*	Germany
Prolifique barbu	*v. ferrugineum*	France
Propo . .	*v. erythrospermum*	U.S.A.
Prosperity . .	*v. lutescens*	,,
Provence, rouge de . . .	*v. milturum*	France
Pudel . . .	*v. leucospermum*	Sweden
Purple Straw .	*v. albidum*	Australia
,, .	*v. lutescens*	U.S.A.
Queen, Fan .	*v. albidum*	Australia
,, White .	,,	England
Rapado quadrata	*c. creticum*	Madeira
Raspinegro .	*du. Reichenbachii*	Spain

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Raspinegro espiga negra . .	*du. libycum*	Spain
Raspinegra espiga pequena . .	*du. leucomelan*	,,
Ratel . . .	*t. dinurum*	U.S.A.
Realforte . .	*du. leucomelan*	Sicily
Recio de Granada	*du. melanopus*	Spain
Red Wave . .	*v. milturum*	U.S.A.
Regadio . .	*v. lutescens*	Spain
Rentpayer . .	,,	England
Reynold's Discovery . .	*t. iodurum*	Australia
Ribeiro . .	*v. erythrospermum*	Portugal
Richelle de Naples	*v. albidum*	France
Rieti . . .	*v. erythrospermum*	Italy
Riet Koorn = Rieti	..	S. Africa
Rivet . . .	*t. dinurum*	England
Rochester Red .	*v. milturum*	U.S.A.
Roermaker .	*v. graecum*	..
Romanella . .	*v. ferrugineum*	Italy
Rooi Klein Koren	,,	S. Africa
Rooi Wol Koren	*v. Delfii*	,,
Roseau . .	*v. albidum*	France
Roseworthy .	,,	Australia
Rosso gentile aristata . .	*v. erythrospermum*	Italy
Rosso gentile mutico . .	*v. milturum*	,,
Rouge barbu d'automne .	*v. ferrugineum*	France
Rouge barbu de Mars . .	,,	,,
Rouge d'Écosse .	*v. milturum*	,,
,, de Mars .	,,	,,
Rouge prolifique barbu . .	*v. ferrugineum*	,,
Roumanian .	,,	Roumania
Rousselin . .	*v. alborubrum*	..
Rubiao . .	*du. hordeiforme*	Portugal
Rudy . . .	*v. erythrospermum*	U.S.A.
Ruio . . .	*du. hordeiforme*	Spain
Rural New Yorker	*v. Hostianum*	U.S.A.
Russian Red .	*v. ferrugineum*	,,
Rymer . .	*v. albidum*	Australia
Saidi . . .	*py. recognitum*	Egypt
St. Helena, Giant	*t. dinurum*	England
St. Laud Rouge .	*v. milturum*	France
Salamanca . .	*t. lusitanicum*	Spain
Salmeron . .	*t. pseudomirabile*	,,
Sammet . .	*v. velutinum*	Sweden
Samogyer Tar .	*v. lutescens*	Hungary

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Sandomir . .	*v. alborubrum*	Russia
Santa Marta .	*du. murciense*	Portugal
Saragolla . .	*du. leucurum*	Italy
Sari Bashak .	*du. hordeiforme*	Asia Minor
Saumur d'Automne .	*v. lutescens*	France
Saumur de Mars	,,	,,
Saxonka . .	*v. erythrospermum*	Russia
Schilf . . .	*v. albidum*	Germany
Schlanstedt Red	*v. milturum*	,,
Schneider . .	*v. albidum*	Australia
Schönrader .	*v. velutinum*	Sweden
Scotch Blood Red . . .	*v. milturum*	Scotland
Seccano . .	*v. erythrospermum*	Spain
Seigle . . .	*v. pyrothrix*	Germany
Seneca Chief .	*v. graecum*	U.S.A.
Seven-headed .	*t. pseudocervinum*	,,
Shirokawa Soshu	*v. erythrospermum*	Japan
Shirokawa Kanagawa .	*v. lutescens*	,,
Shirokawa Yenidashi .	*v. erythrospermum*	,,
Shirreff's White .	*v. graecum*	England
Shutar Dandan .	*o. insigne*	Khorasan
Siah Das . .	*o. notabile*	,,
Sibley's Golden .	*v. ferrugineum*	U.S.A.
Sicilian . .	*c. creticum*	..
Siciliani . .	*du. Valenciae*	Italy
,, . .	*du. italicum*	,,
Sicilio . .	*t. buccale*	..
Siebritz . .	*v. erythroleucon*	S. Africa
Silver Dollar .	*v. erythrospermum*	U.S.A.
,, King .	*v. velutinum*	,,
,, Sheaf .	*v. erythrospermum*	,,
Smyrna = Miracle	..	..
Snowdrop .	*v. lutescens*	England
,, .	*v. leucospermum*	N. Zealand
Solina d'Ascoli .	*v. ferrugineum*	Spain
Sonora . .	*v. Delfii*	U.S.A.
Sorrentino .	*du. affine*	Germany
Spalding's Prolific	*v. milturum*	England
Squarehead .	*v. lutescens*	,,
Squarehead's Master . . .	*v. milturum*	,,
Standard Red .	,,	,,
Standup, Main's	*v. albidum*	,,
,, Red .	*v. milturum*	,,
,, White	*v. albidum*	,,
Stanley . .	*v. milturum*	Canada
Starling . .	*v. albidum*	England
Steinwedel .	,,	Australia

Name.	Race and Variety.	Country of Origin or where chiefly grown
Suède rouge de Mars . .	*v. ferrugineum*	France
Sun . . .	*v. lutescens*	Sweden
Sunagawa . .	*v. ferrugineum*	Japan
Superlative .	*v. alborubrum*	Canada
Swan . . .	*v. lutescens*	England
Taganrock .	*t. gentile*	..
Talavera . .	*v. albidum*	England
Talavera Belle Vue	,,	,,
Tarragon . .	,,	Australia
Tasmanian Red.	*v. ferrugineum*	..
Taunton Dean .	*v. lutescens*	England
Temporas de Coruche . .	*v. ferrugineum*	Portugal
Teverson . .	*v. milturum*	England
Theiss = Banat .	..	Hungary
Thew . .	*v. albidum*	Australia
Thickset Suffolk = Hickling .	..	England
Tom Thumb .	*v. albidum*	N. Zealand
Touzelle anone .	*v. lutescens*	France
Touzelle de Provence . .	*v. milturum*	,,
Touzelle Velvet .	*v. leucospermum*	,,
Treasure White.	*v. albidum*	N. Zealand
Tresor . .	*v. lutescens*	France
Trimenia . .	*du. affine*	Italy
Triumph . .	*v. albidum*	Australia
Trump . .	*v. lutescens*	..
,, . . .	*v. albidum*	..
Tüchtiger Landwirth . .	*v. lutescens*	Germany
Tukur Sinde .	*di. Arraseita*	Abyssinia
,, White .	..	,,
Tunis . . .	*py. pseudo-compressum*	Egypt
Tunstall . .	*v. leucospermum*	..
Turkey . .	*t. iodurum*	France
,, Red .	*v. erythrospermum*	U.S.A.
Tuscan Red .	*v. lutescens*	N. Zealand
,, White .	*v. albidum*	,,
Tuscan Solid Straw . .	,,	,,
Tusela . .	*v. lutescens*	Argentina
Tystofte Smaahvete . .	,,	Denmark
Tystofte Standhvete . .	,,	,,
Ulka . . .	*v. erythrospermum*	Russia
,, . . .	*v. ferrugineum*	,,

Name.	Race and Variety.	Country of Origin or where chiefly grown.
Ulka	*v. lutescens*	Russia
,,	*v. milturum*	,,
Upper Cut	*v. albidum*	Australia
Urtoba	,,	Germany
Usher's Red	*v. erythrospermum*	Australia
Utendorf	*v. milturum*	Switzerland
Valley	*v. erythrospermum*	U.S.A.
Velouté, Blanc	*v. leucospermum*	France
Velvet, Blue	*v. cyanothrix*	Persia
,, Chaff	*v. leucospermum*	England
,, Red	*v. barbarossa*	..
Verdeal	*du. leucurum*	Spain
Vermelejoilo	*du. hordeiforme*	Portugal
Vermelho fino	*du. aegypticum*	,,
Victor	*v. albidum*	England
Victoria de Mars	*v. erythrospermum*	France
,, Red	*v. lutescens*	,,
,, White	*v. albidum*	England
Victris	,,	..
Vroe Baard=Ecksteen	..	..
Wallace	*v. albidum*	Australia
Warden	*v. lutescens*	,,
Wards Prolific	*v. alborubrum*	Australia
Warren	*v. albidum*	,,
Wave, Red	*v. milturum*	U.S.A.
White Straw Red	*v. lutescens*	England
Whittington's White	*v. albidum*	,,
Wilhelmina	,,	Holland
Willem I.	,,	,,
Windsor Early	*v. alborubrum*	Canada
Windsor Forest	*v. lutescens*	England
Wit Klein Koren	*v. graecum*	S. Africa
Wit Wol Koren	*v. leucospermum*	,,
Wonder, Red	*v. erythrospermum*	U.S.A.
Xeixa	*v. alborubrum*	Spain
Xeixa invernanca	*v. ferrugineum*	,,
Xeres	*du. leucurum*	France
Yandilla King	*v. albidum*	Australia
Yaroslav	*v. ferrugineum*	U.S.A.
Yeoman	*v. lutescens*	England
Zeeland	*v. albidum*	..
Zimmerman	*v. lutescens*	U.S.A.
Zwaart Baard	*du. melanopus*	S. Africa

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Printed by R. & R. Clark, Limited, *Edinburgh.*